Assessing RV Thickness, Size and Function

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UTHSCSA and ALMMVAH
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Ares Pasipoularides

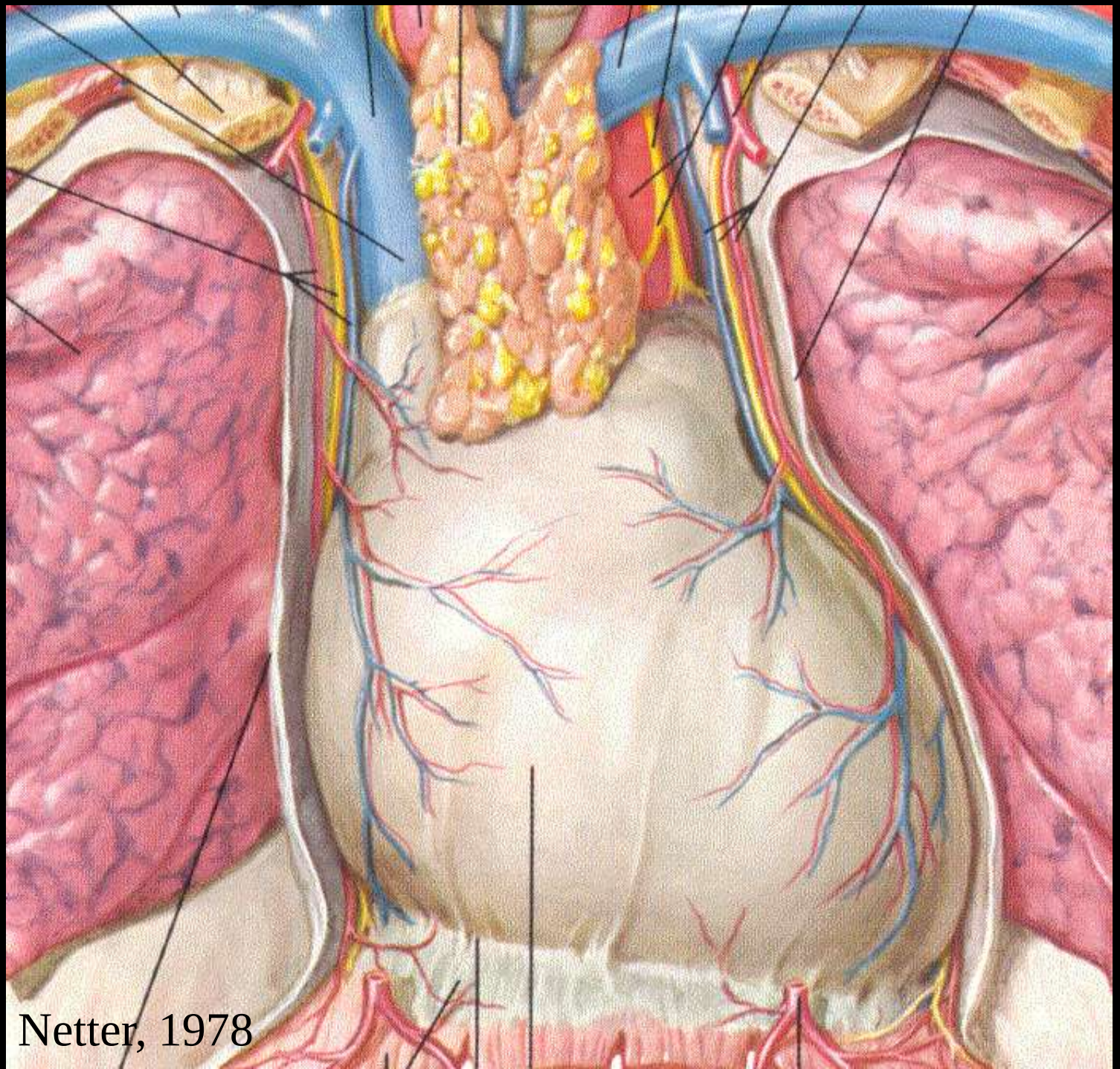
Assessing RV Performance

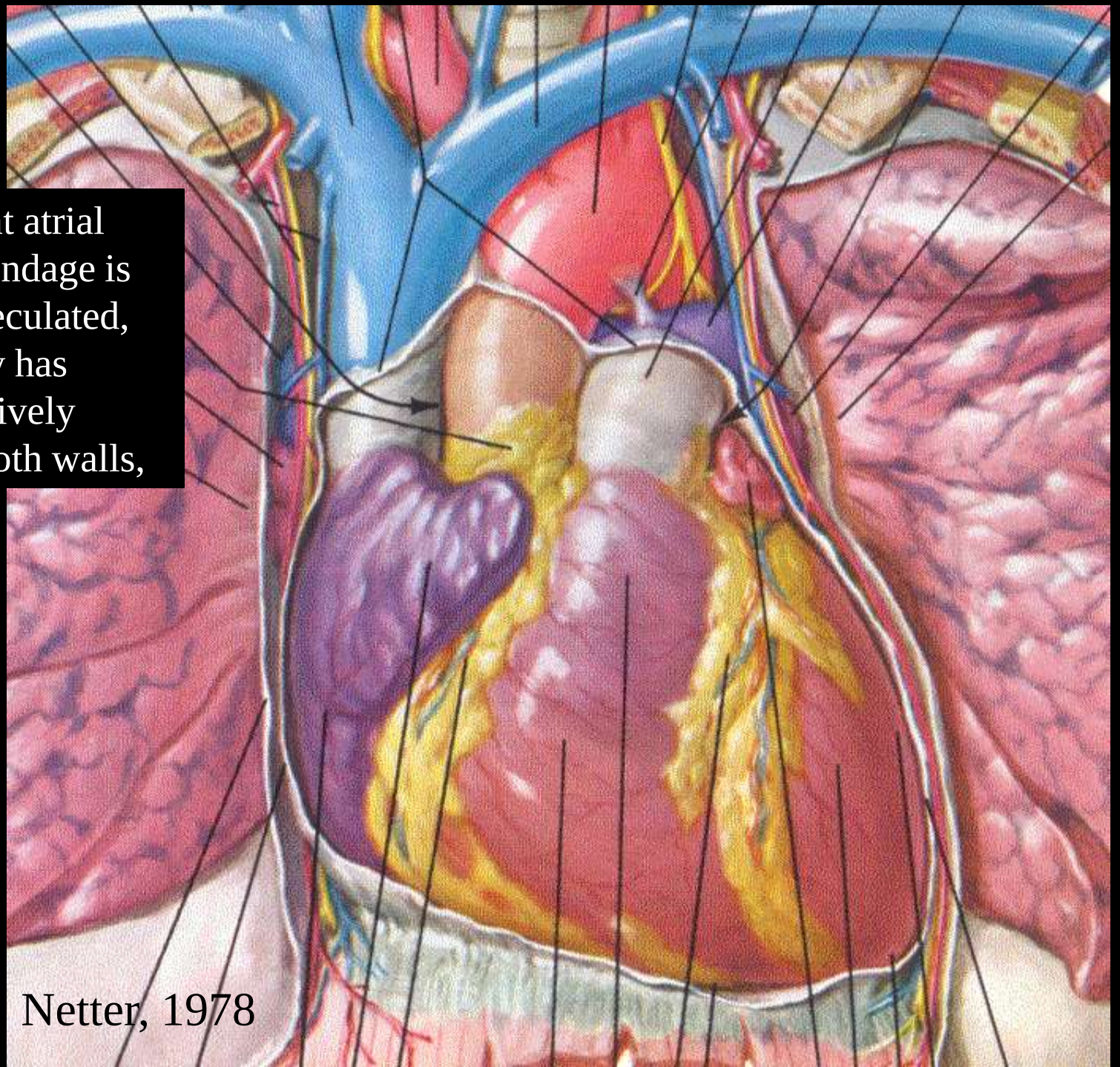
- Normal RV anatomy and physiology
- Assessing RV size
- Assessing RV function

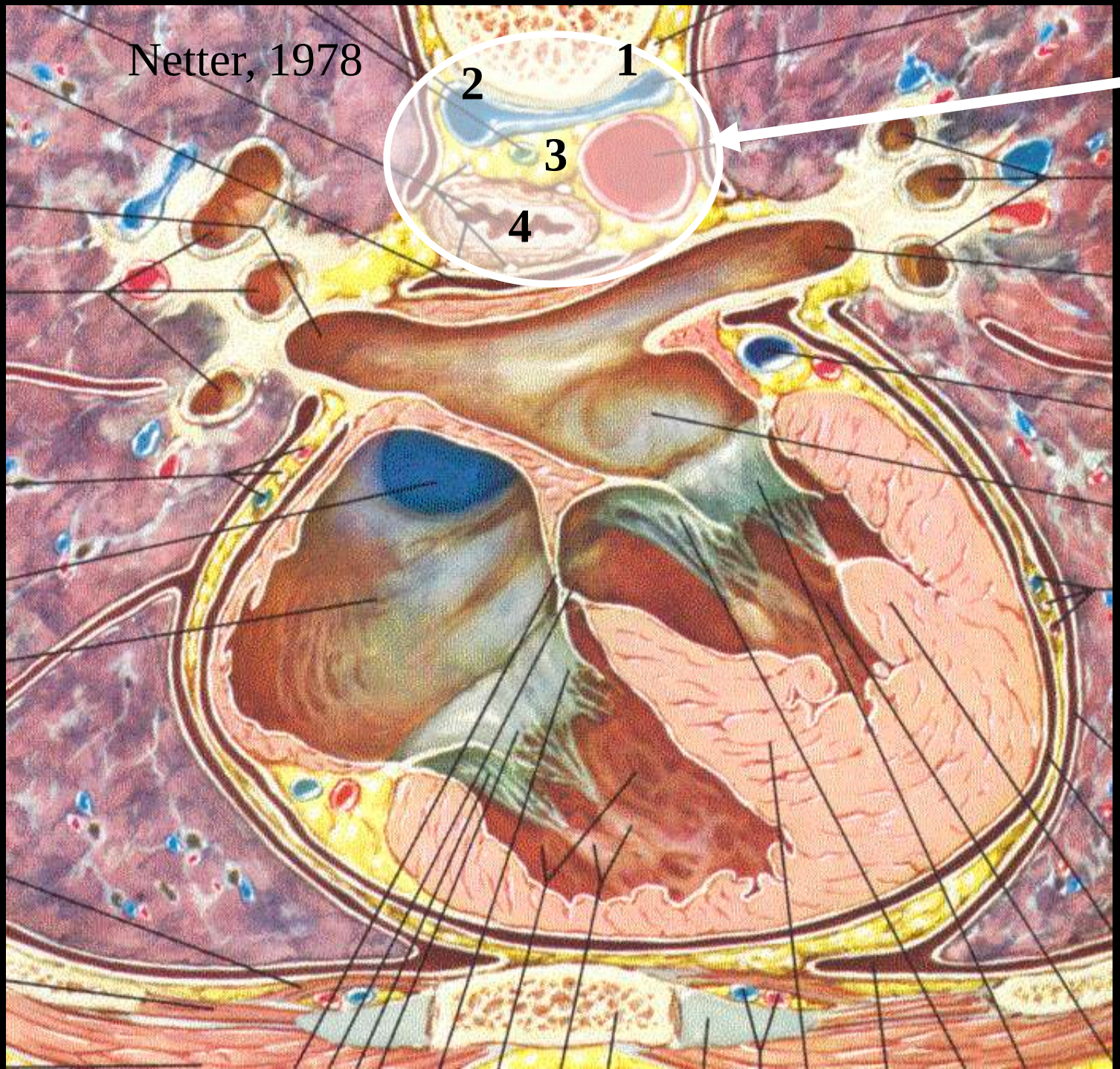
Normal RV Anatomy

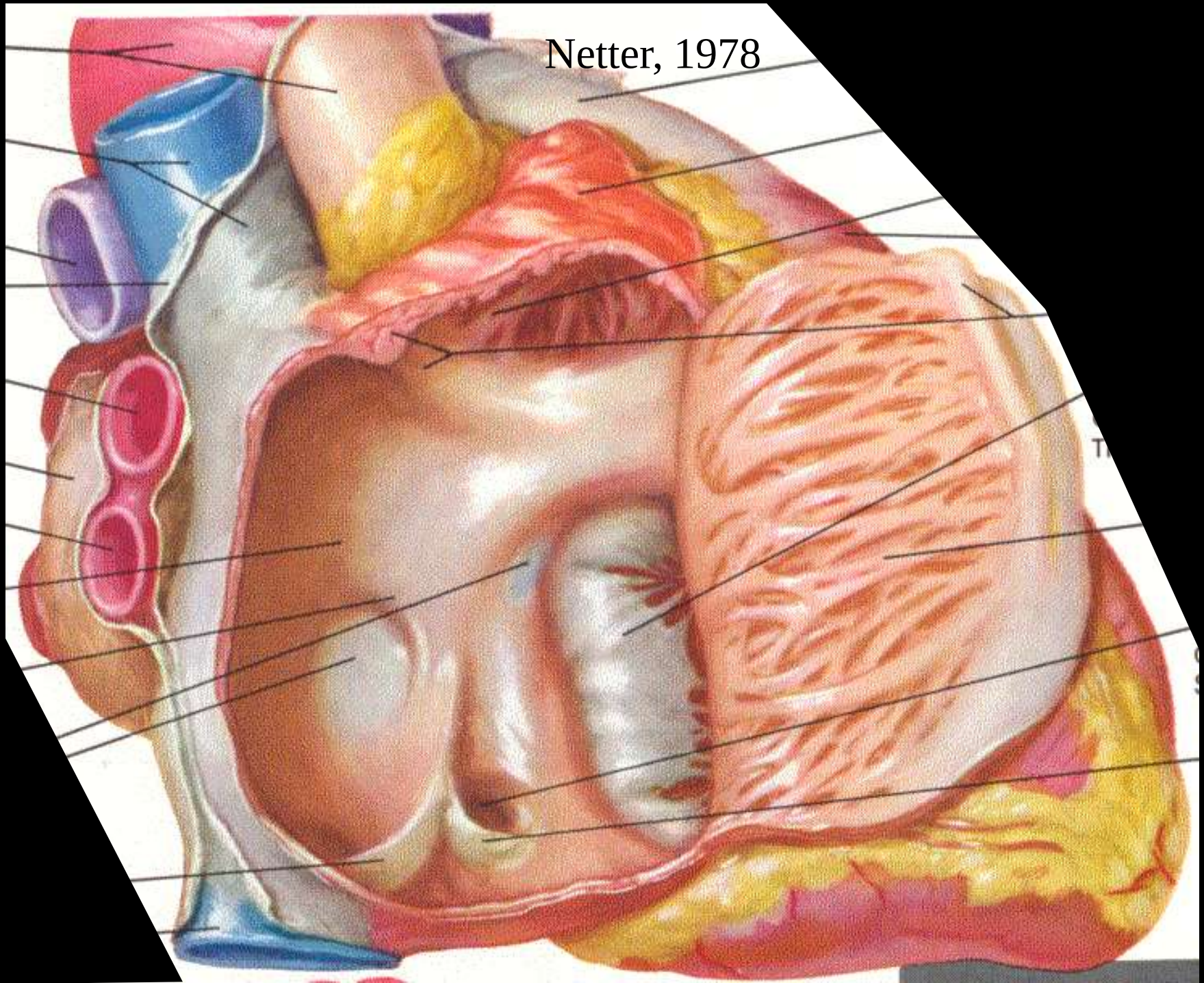
Structurally complex

- Inflow, body, ouflow (conus, infundibulum)
  - Angle inflow to outflow: 60 degrees
- Crescent in cross section
  - Large surface/volume ratio (small changes in septal to free wall distance can cause large volume displacement)
  - Less myocardial shortening for stroke volume
  - Inefficient if afterload increases
- Triangular in lateral projection
- Irregular inner walls, 4-5 mm thick, heavier trabeculation than LV, infundibulum smooth


Netter, 1978

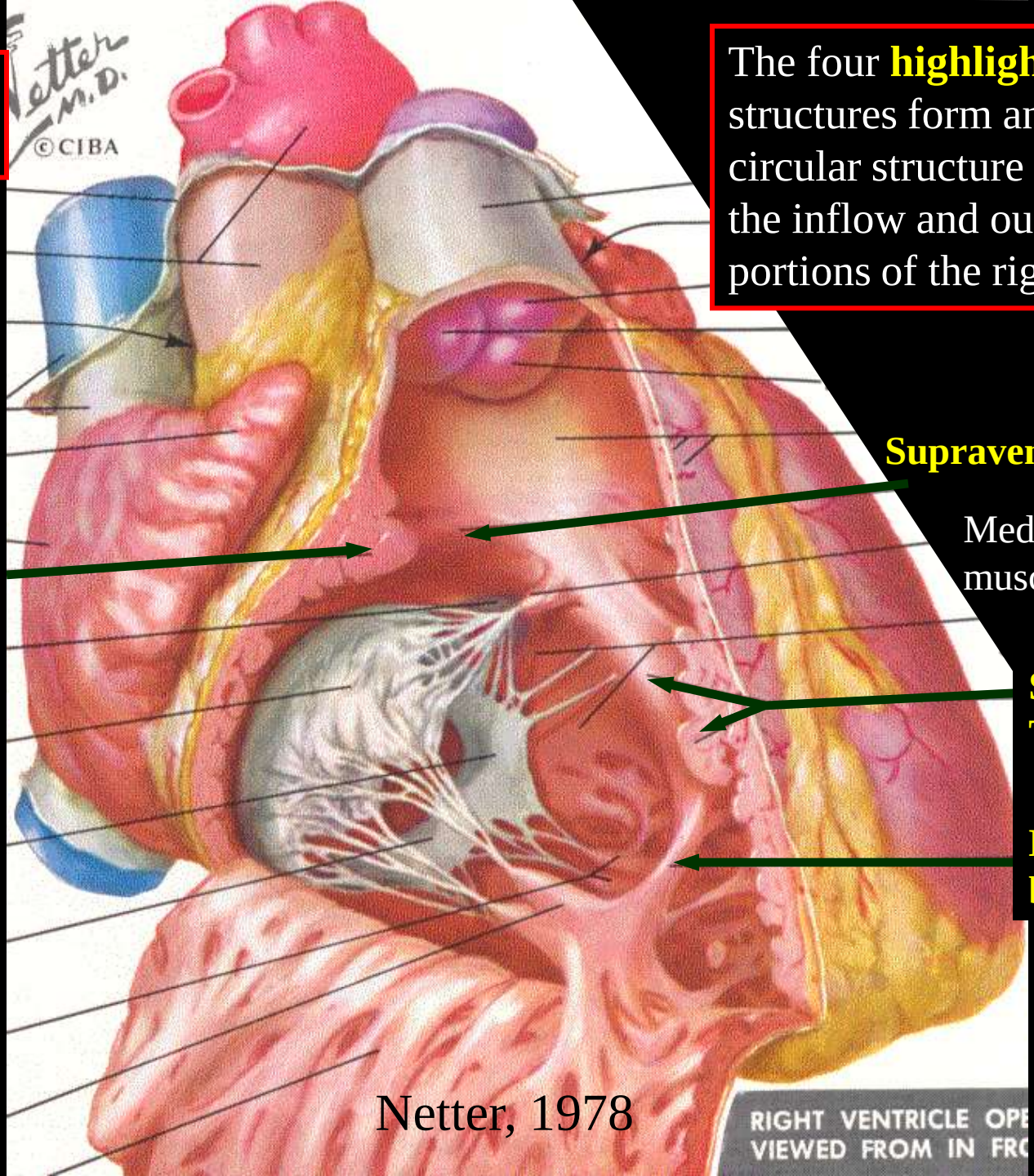

Right atrial appendage is trabeculated, body has relatively smooth walls,
Netter, 1978


Netter, 1978
1
2
3
4
Four
birds


Netter, 1978

The RV has a conus

The four **highlighted** structures form an almost circular structure separating the inflow and outflow portions of the right ventricle



Supraventricular crest

Medial Papillary muscle

Parietal Band

Septomarginal Trabeculation

Anterior

Septal

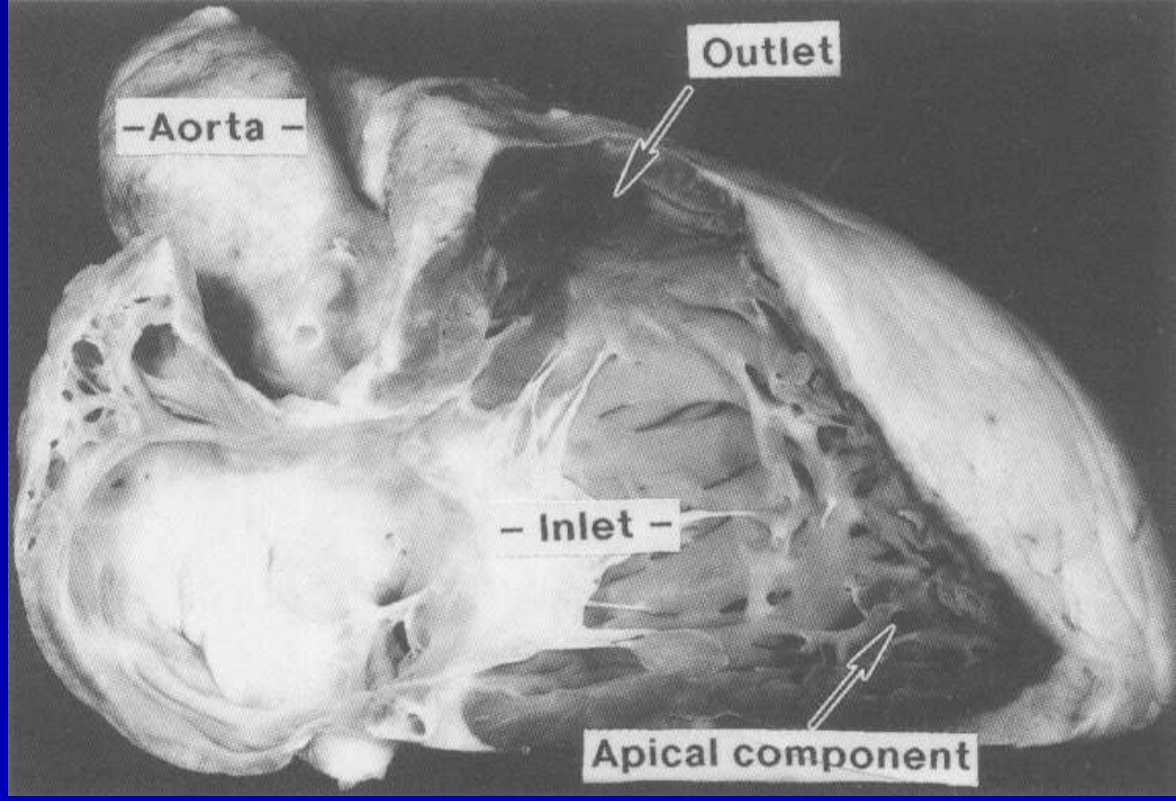
Moderator band

Inferior

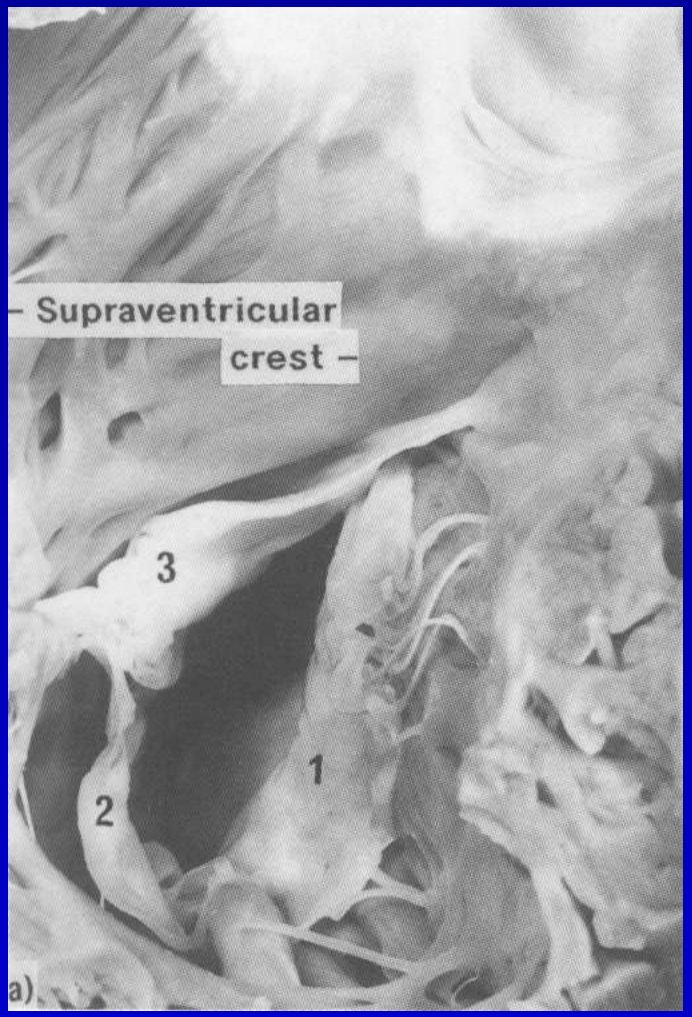
Anterior Papillary muscle

Netter, 1978

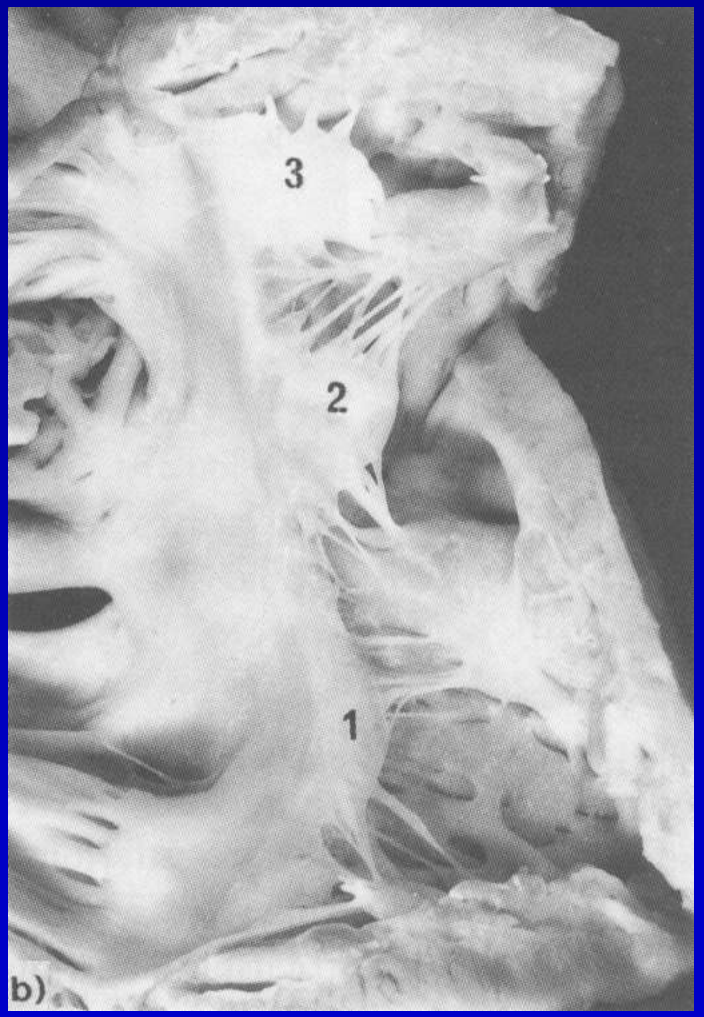
RV trabeculations are coarser than LV



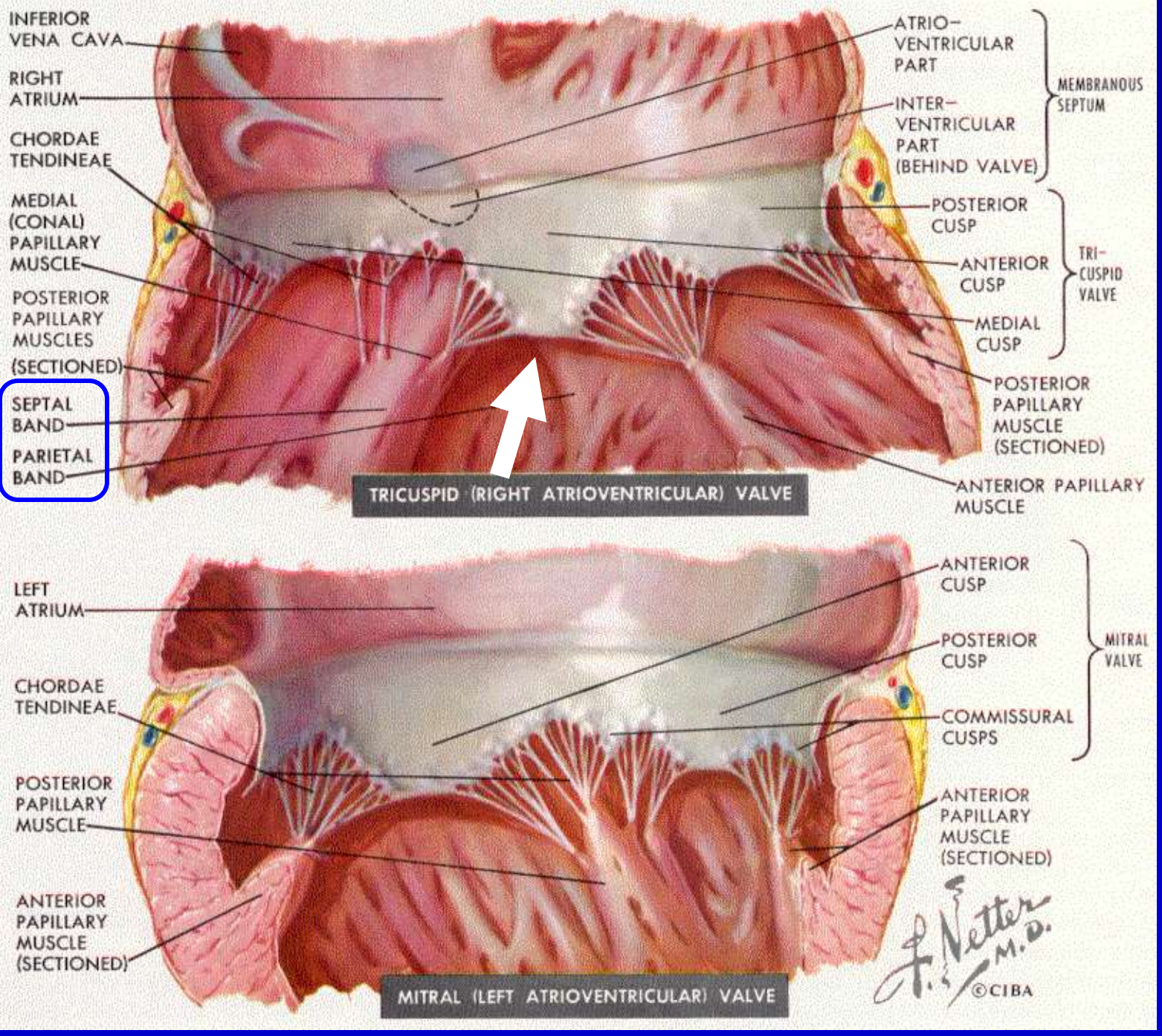
Tricuspid Valve Anatomy



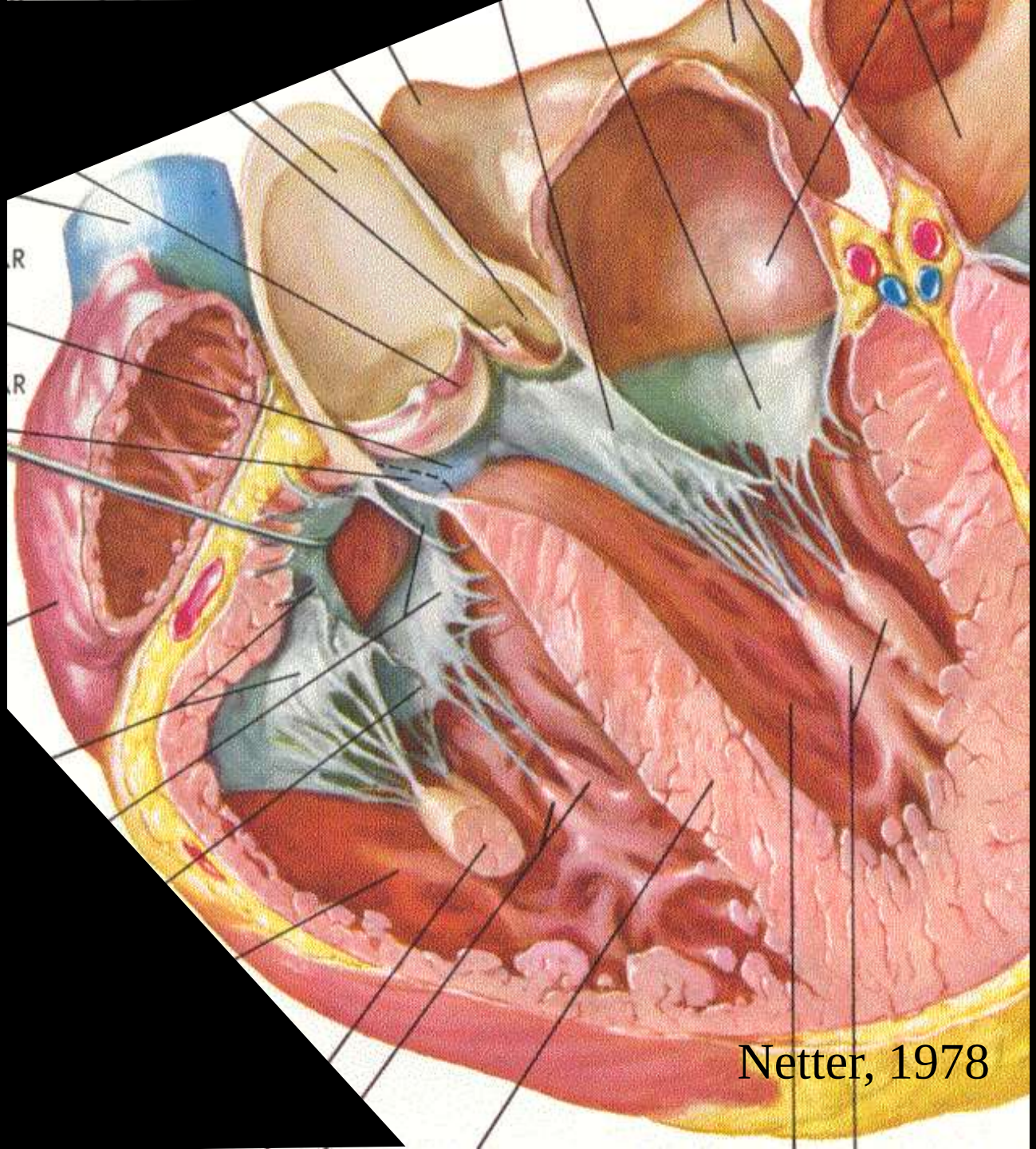
1- septal
2- posterior (inferior)
3- anterior (superior)



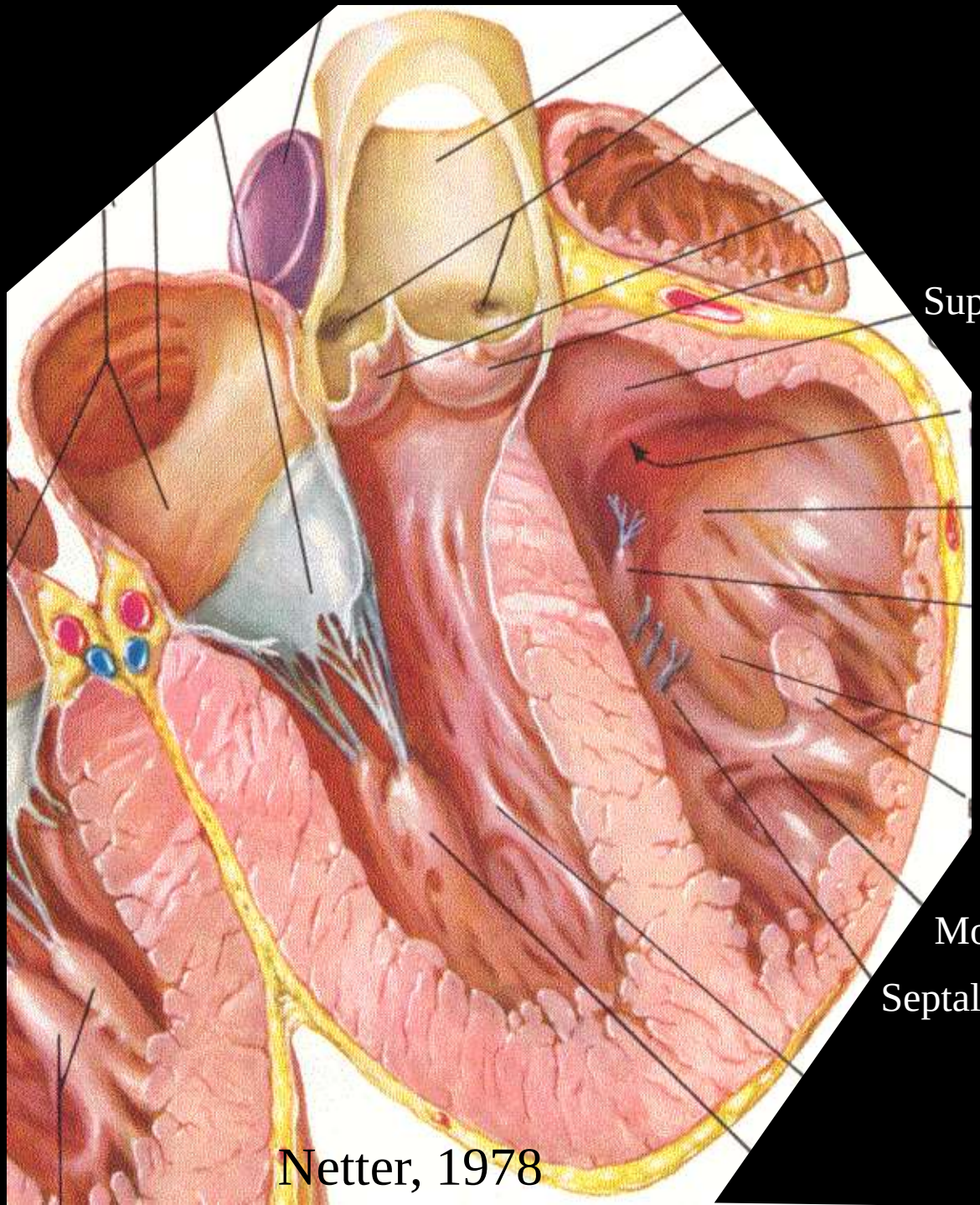
Redington AN et al, 1998



Large white arrow indicates RV outflow



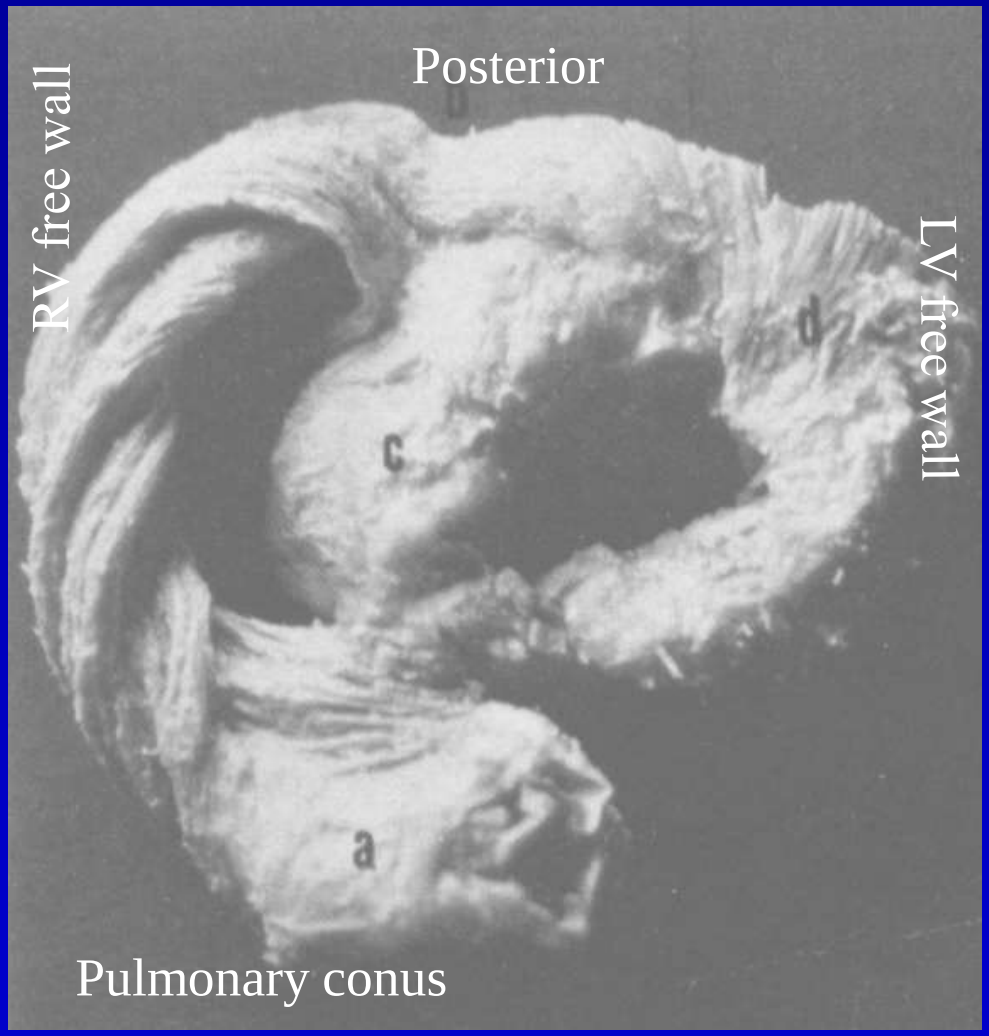
Netter, 1978



Netter, 1978

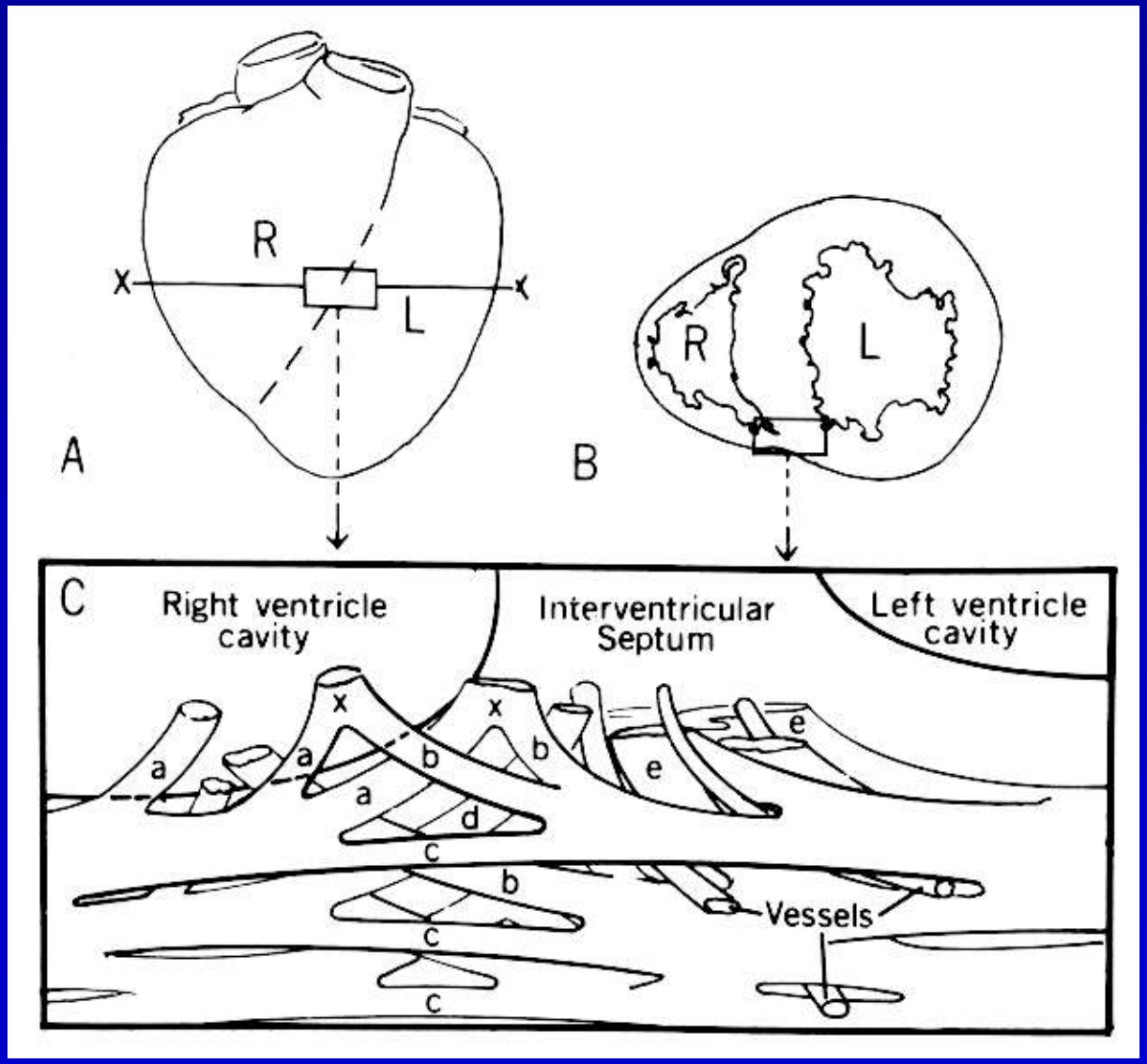
Fiber Geometry

Imbrication inward to the right



Porcine cardiac base

Fiber geometry - 2



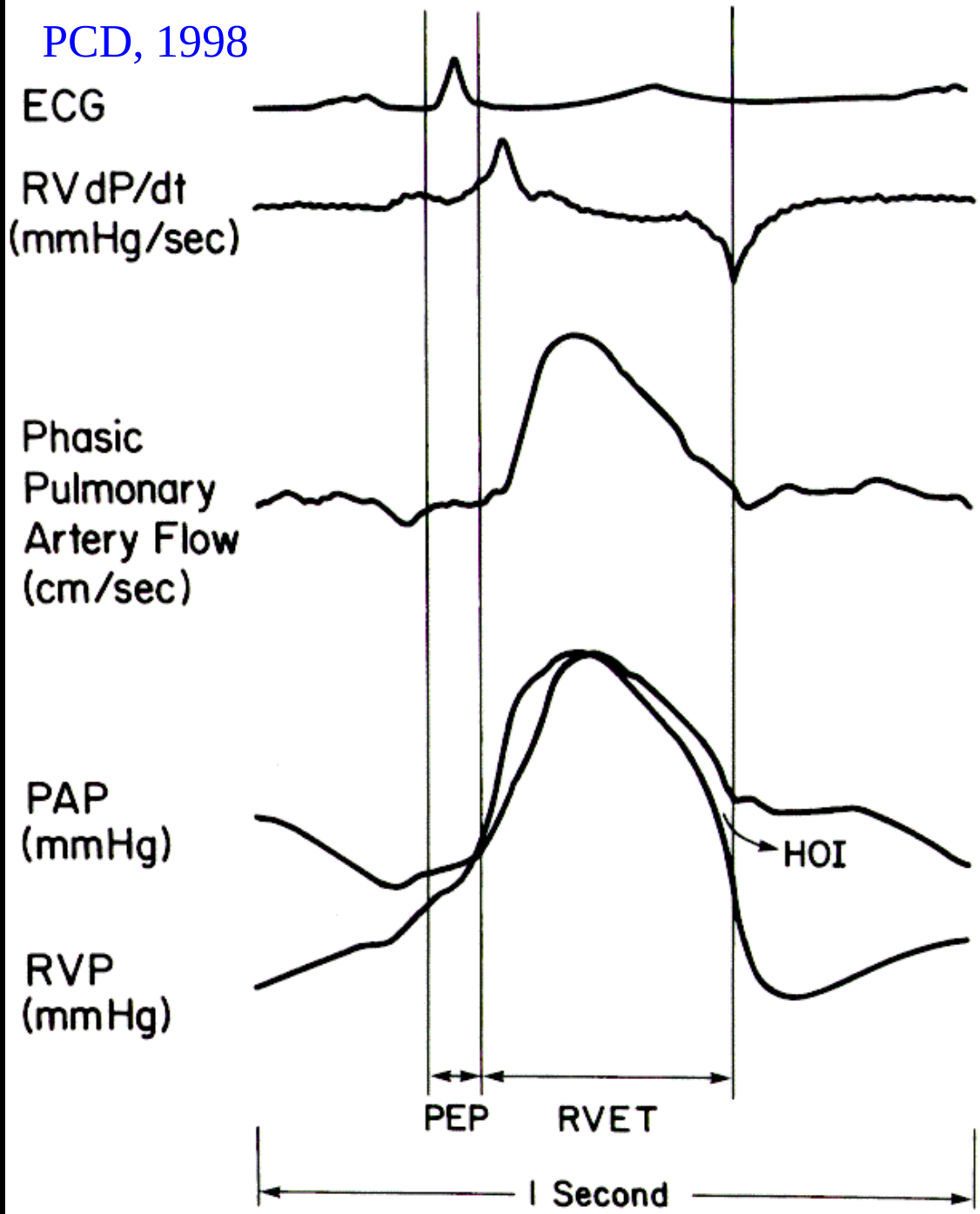
Bifurcation of cardiac fibers at anterior IV sulcus.

a. RV fibers branching into RV trabeculae
b. LV fibers branching into RV trabeculae
c. superficial fiber paths of RV and LV walls
d. RV fiber branching into septum
e. LV fiber branching into septum

Normal RV Physiology

- About 20-40% of RV systolic pressure and output result from LV contraction.
- Structure is optimized for low impedance output
- Normal pressures
  - RV or PA Systolic: 15-28 (24)
  - RV end-diastolic: 0-8 (4)
  - PA diastolic: 5-16 (10)
  - PA mean: 10-22 (16)
- Stroke index 47 ml/m2 (30-65), arteriolar resistance 70 (45-120), total pulmonary 200
- RV ejection fraction lower and end diastolic volume higher than LV

PCD, 1998

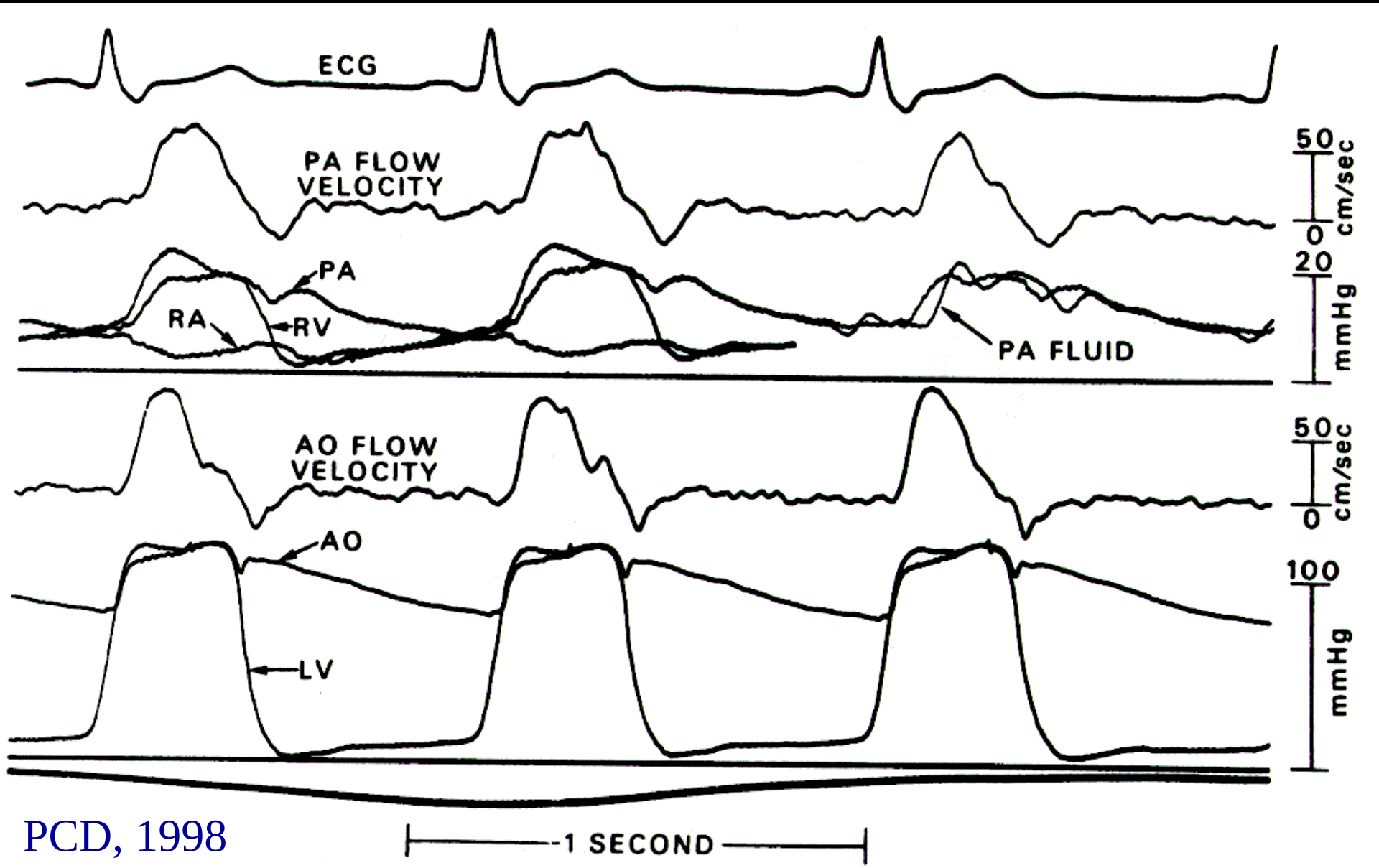


Dell'Italia LJ, Walsh RA.
Am Heart J 1988;116:1289-97.

Normal RV Physiology

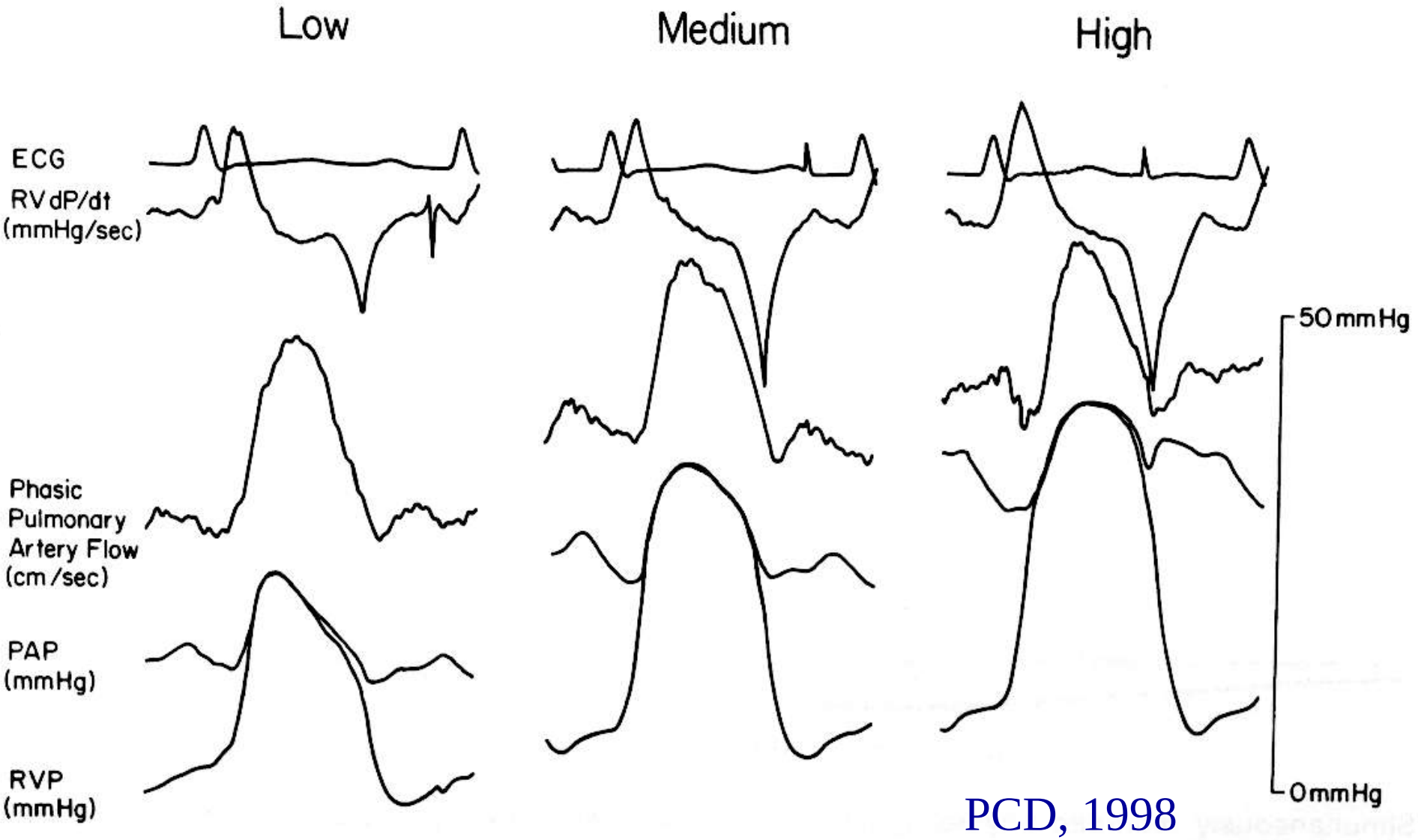
- Low afterload system
  - Mean PA pressure, pulse pressure and vascular resistance are 1/6 systemic
  - Pulse wave velocity is about half of systemic
- Ventricular interdependence
  - Common pericardial constraint
  - Common myocardial fiber bundles
  - Common septal wall
  - Both diastole and systole are affected

Simultaneous Right and Left Heart Waveforms



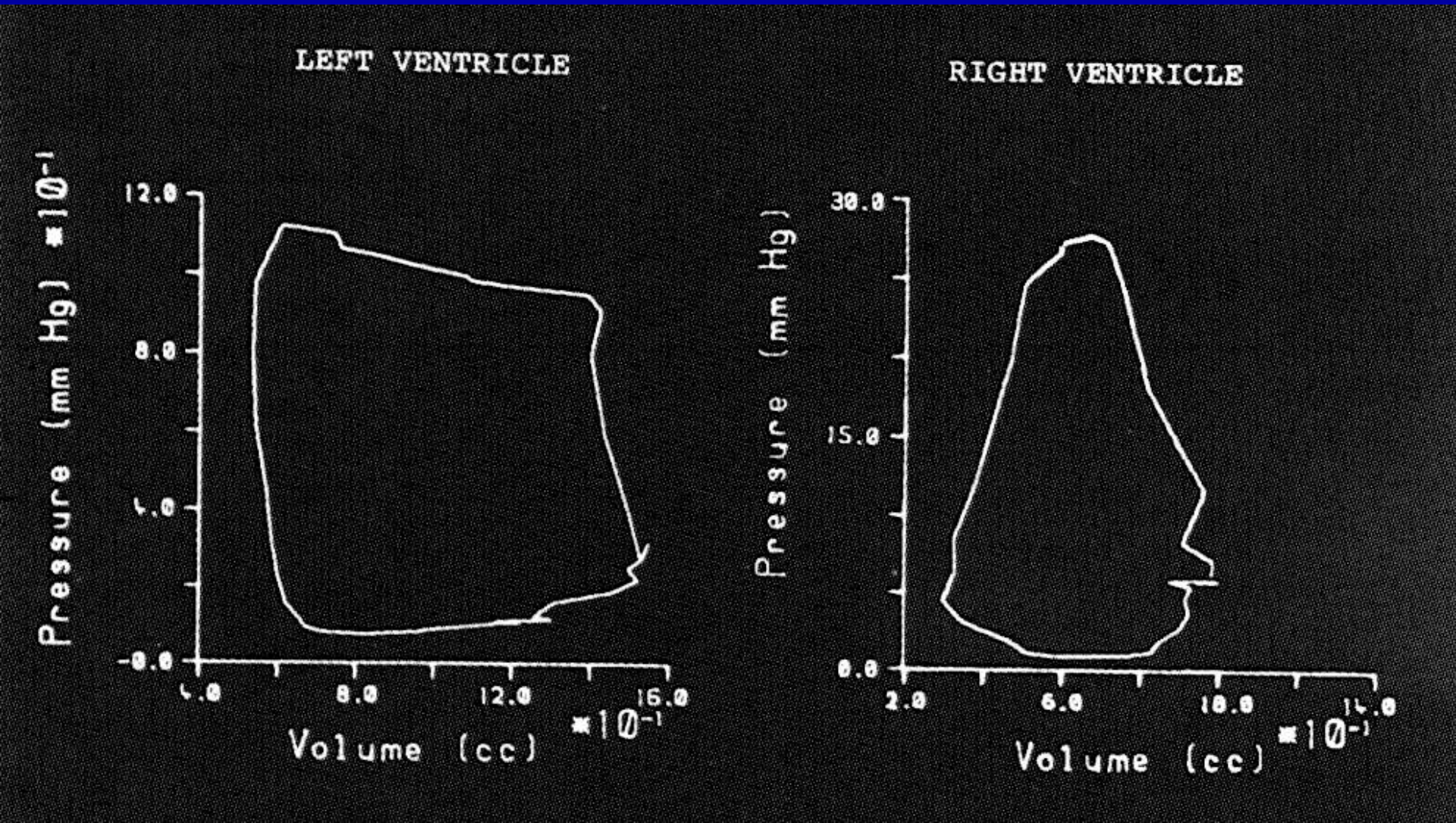
PCD, 1998

Acute Response to Pressure Load



PCD, 1998

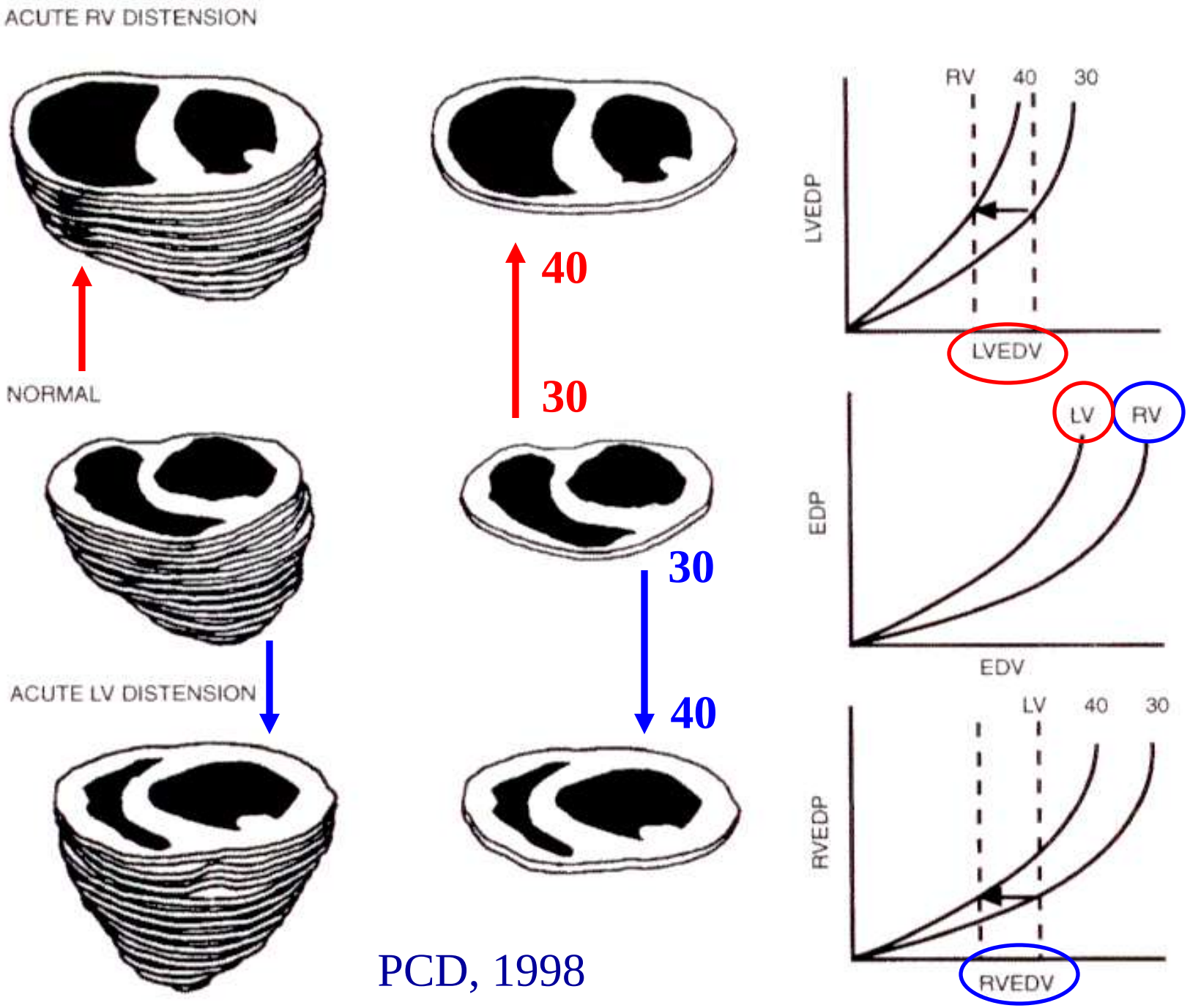
RV Pressure-Volume Loop



Diastolic Ventricular Interaction

- Increasing RV volume shifts the LV diastolic pressure-volume curve upward (making the LV appear noncompliant)
- Increasing LV volume and pressure shifts the RV pressure-volume curve upward and to the left (making the RV appear noncompliant)
- This occurs even if the pericardium is absent, but more pronounced if pericardium present, and still more if pericardial constraint is augmented by constriction or tamponade

PCD, 1998

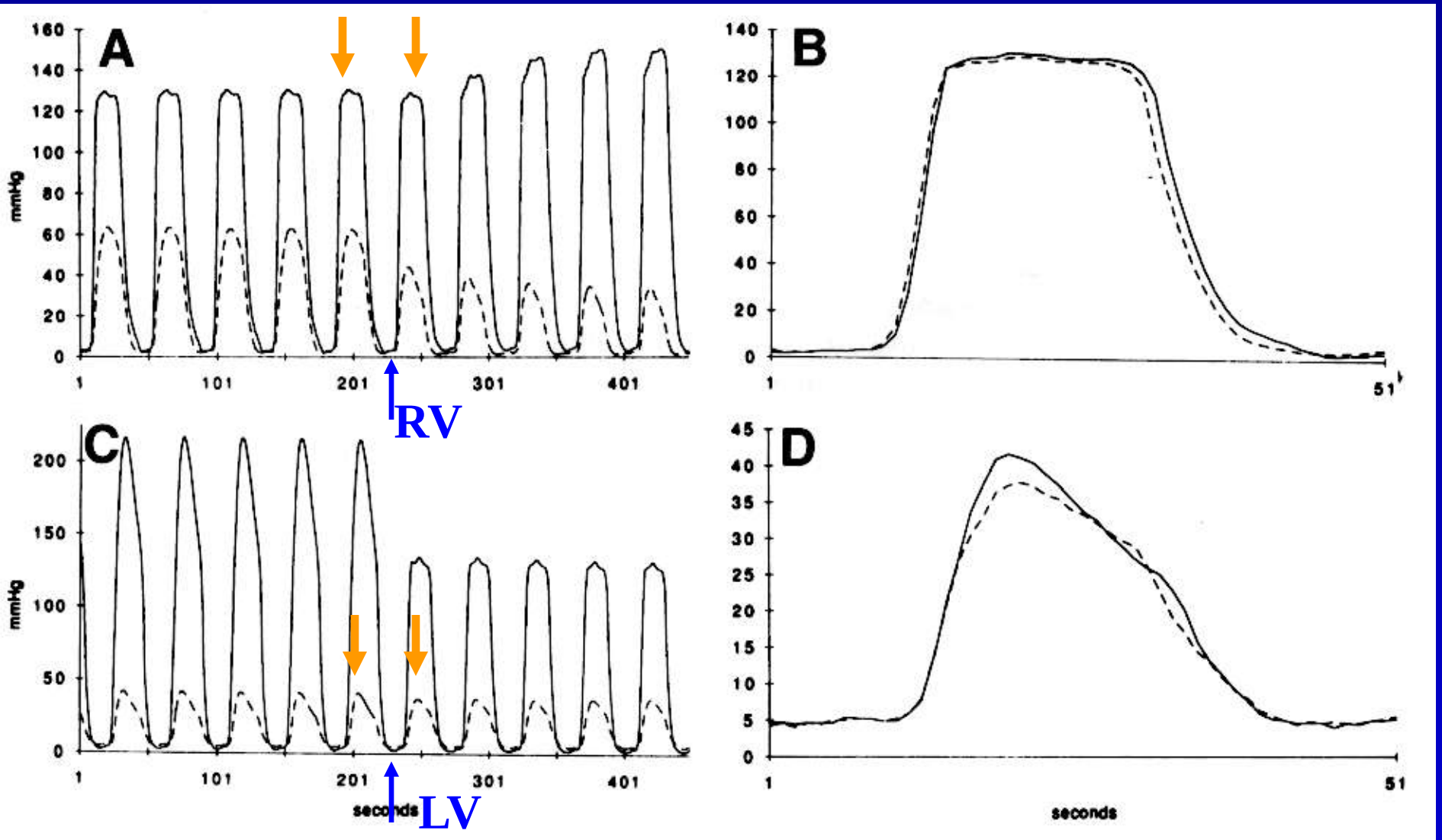

ACUTE RV DISTENSION
NORMAL
40
30
30
40
ACUTE LV DISTENSION
RV
40
30
LVEDP
LVEDV
LV
RV
EDP
EDV
LV
40
30
RVEDP
RVEDV

PCD, 1998

Systolic Ventricular Interaction

- Increased RV systolic pressure augments LV systolic pressure a little (and *vice versa*)
- RV dP/dt is affected by LV dP/dt, accentuated by RV or LV endocardial pacing
- One experimental preparation calculated that the LV contributed > 50% of RV systolic pressure and > 50% of PA flow
- Interaction augmented by compliant septum, and decreased by stiff septum, probably not affected by pericardium (in contrast to diastolic interaction)

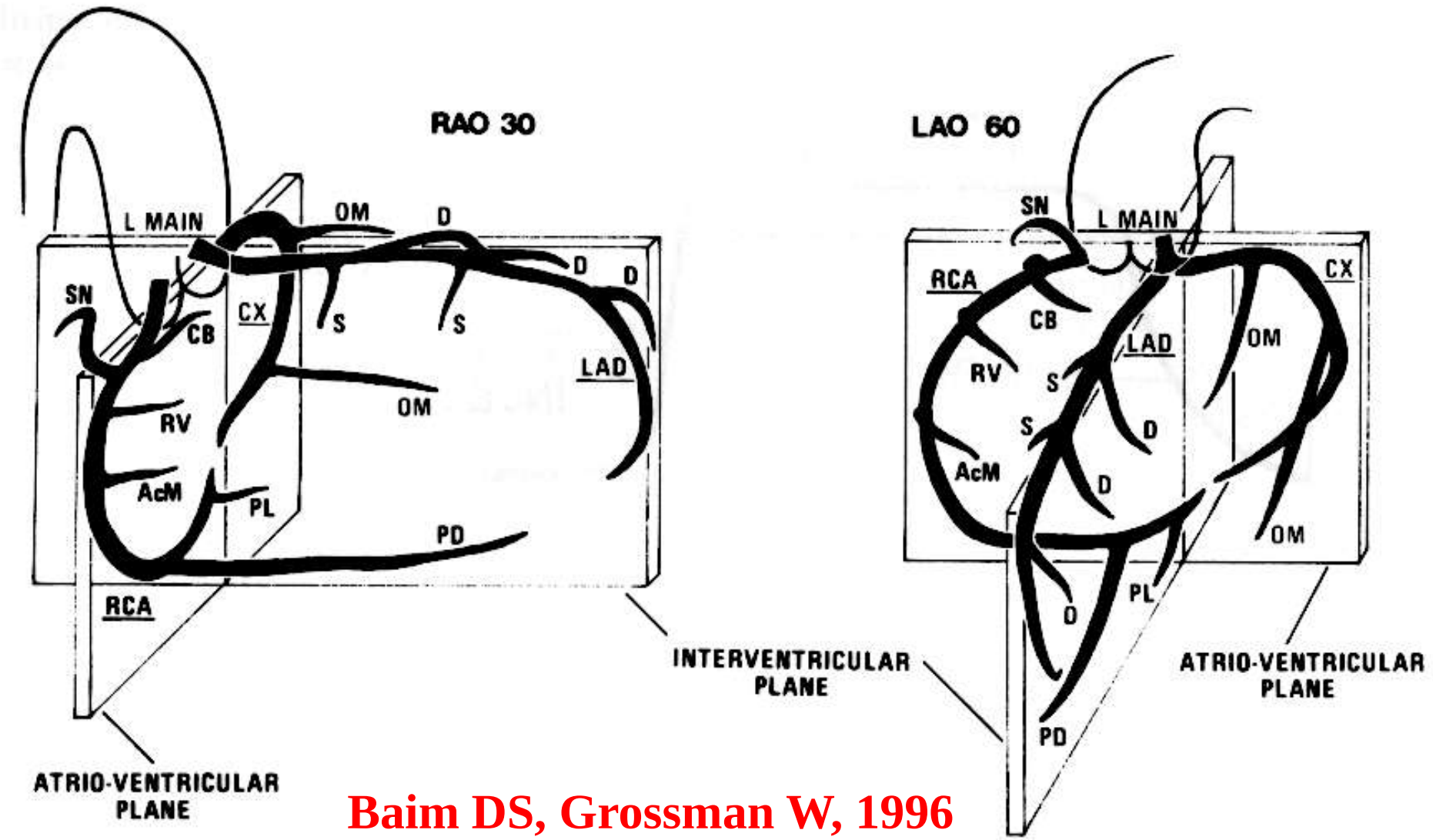
PCD, 1998



Panel B and D: dashed line is pressure on beat after constriction release. Blue arrow: pressure release.

PCD, 1998

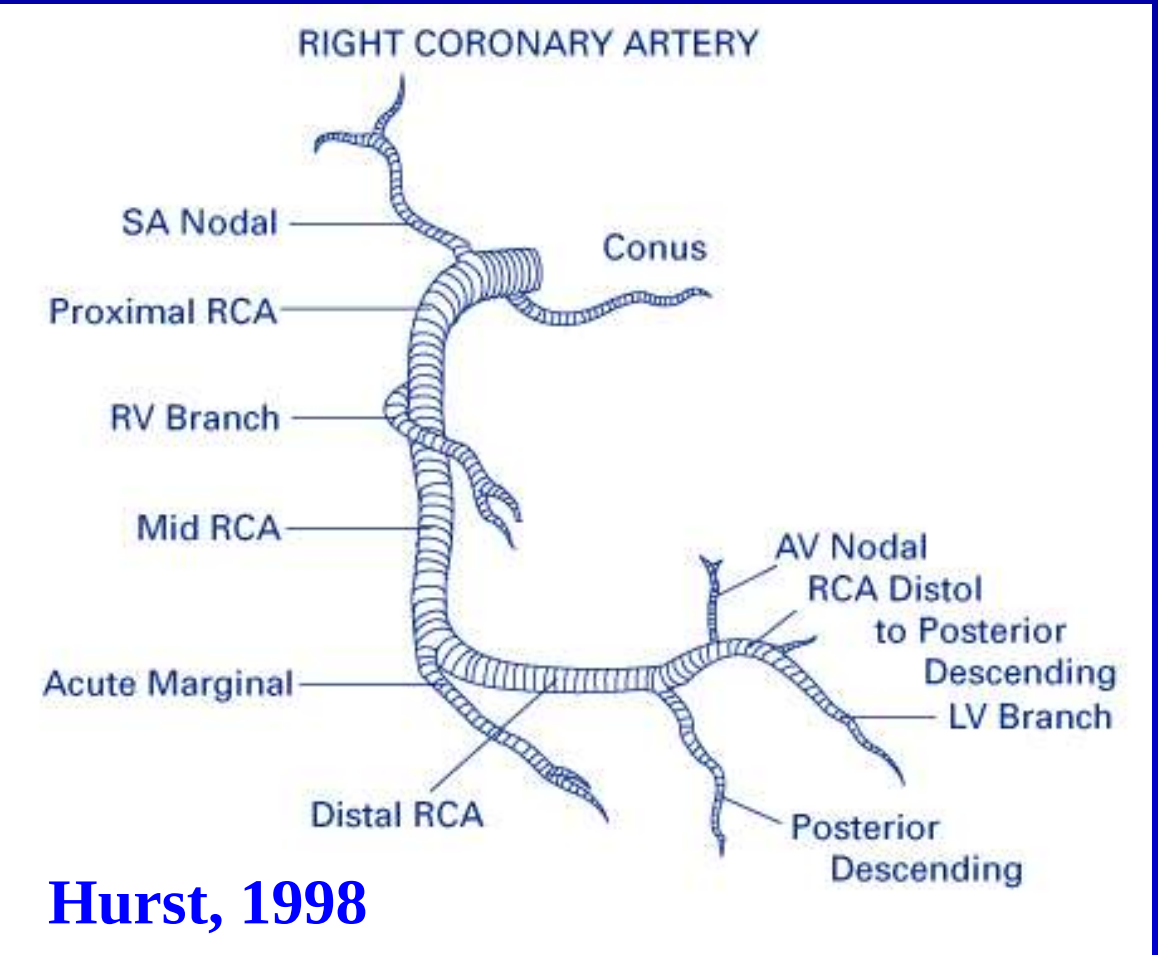
Right ventricular blood supply



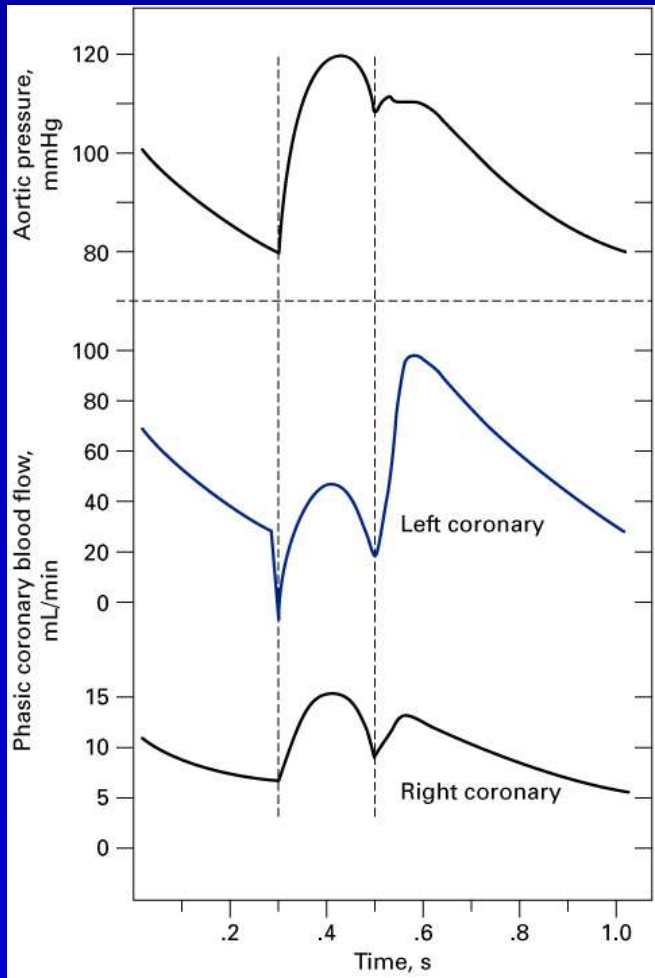
Baim DS, Grossman W, 1996

Right ventricular blood supply

- From the RV branch of the right coronary artery, and the acute marginal branch



Hurst, 1998



RV Response to a Pressure Load

- **Acquired** pressure load
  - Pulmonary emboli
  - Primary pulmonary hypertension
  - Secondary pulmonary hypertension
    - LV dysfunction, mitral disease
    - COPD, emphysema (cor pulmonale results in increased wall thickness, myocyte diameter and fibrosis amount in both LV and RV)
    - Eisenmenger's physiology (ASD, VSD, PDA)
- **Congenital** pressure load
  - Congenitally corrected transposition of the great vessels (L-transposition)
  - PS (any level), ToF

Acute RV Pressure Load

- RV response
  - decrease cardiac output
  - Increase RV systolic pressure
  - RV EDV and ESV increase
  - RV EF decreases
  - Late: RV failure
- LV response
  - Decrease LV EF, SV, EDV, ESV, and increase in IVRT
  - LV shape: decrease mainly in septal-lateral axis, both systole and diastole

Series interaction considerations are also important

PCD, 1998

RV response to a volume load

- Congenital volume load
  - ASD, partial anomalous pulmonary venous return
- Acquired volume load
  - TR
  - PR

Hemodynamic Effects of RVVO
ASD, TR, or PR

- RV volume increased, RV EF normal
- LV
  - volume decreased, shape more distorted in diastole, more normal in systole
  - EF normal or slightly decreased
  - LVEDP normal
  - atrial kick diminished
  - SV and LV SWI decreased (myocyte function probably normal)
  - PEP increased and LVET decreased, and LV response to exercise may be decreased

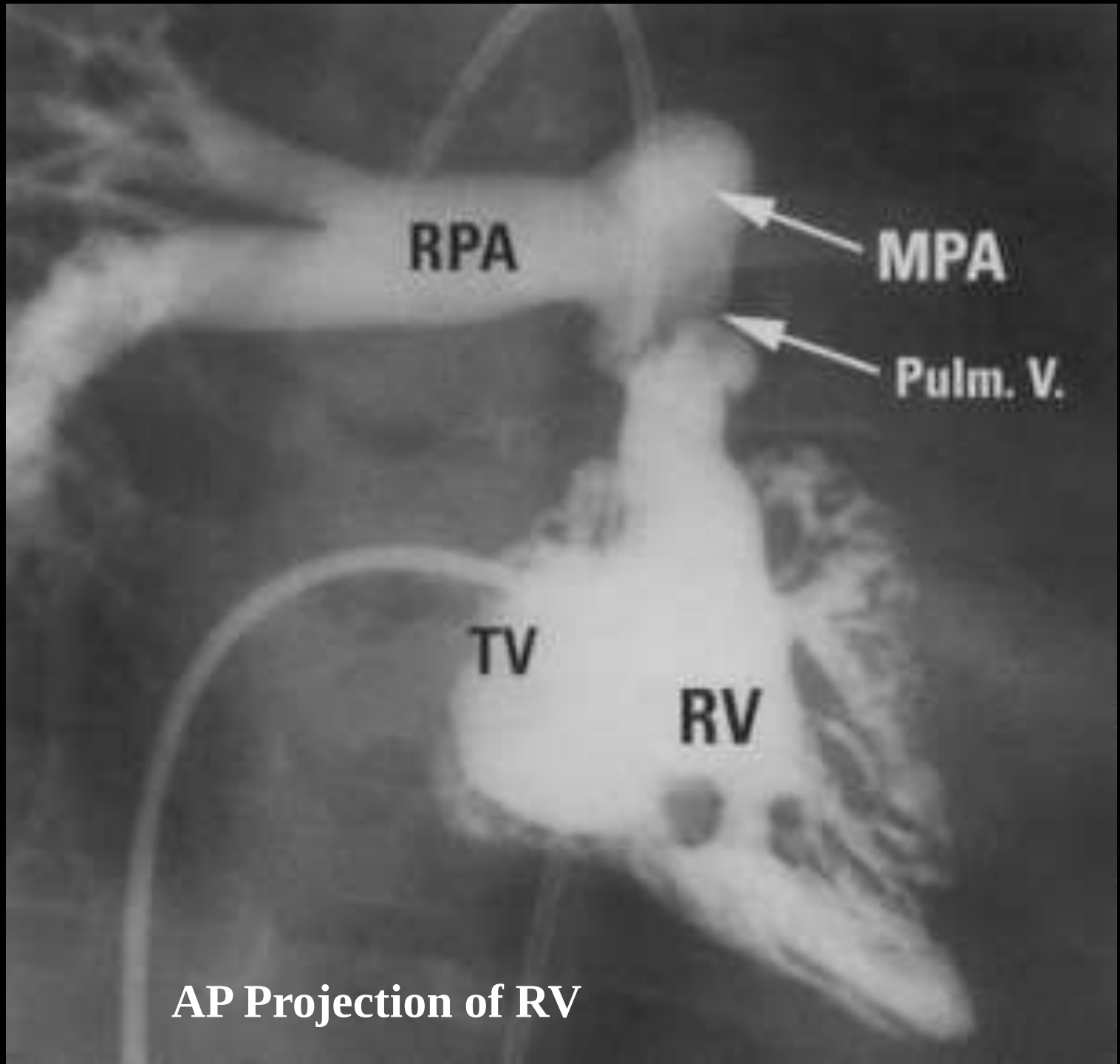
PCD, 1998

Management Considerations in RV Loads

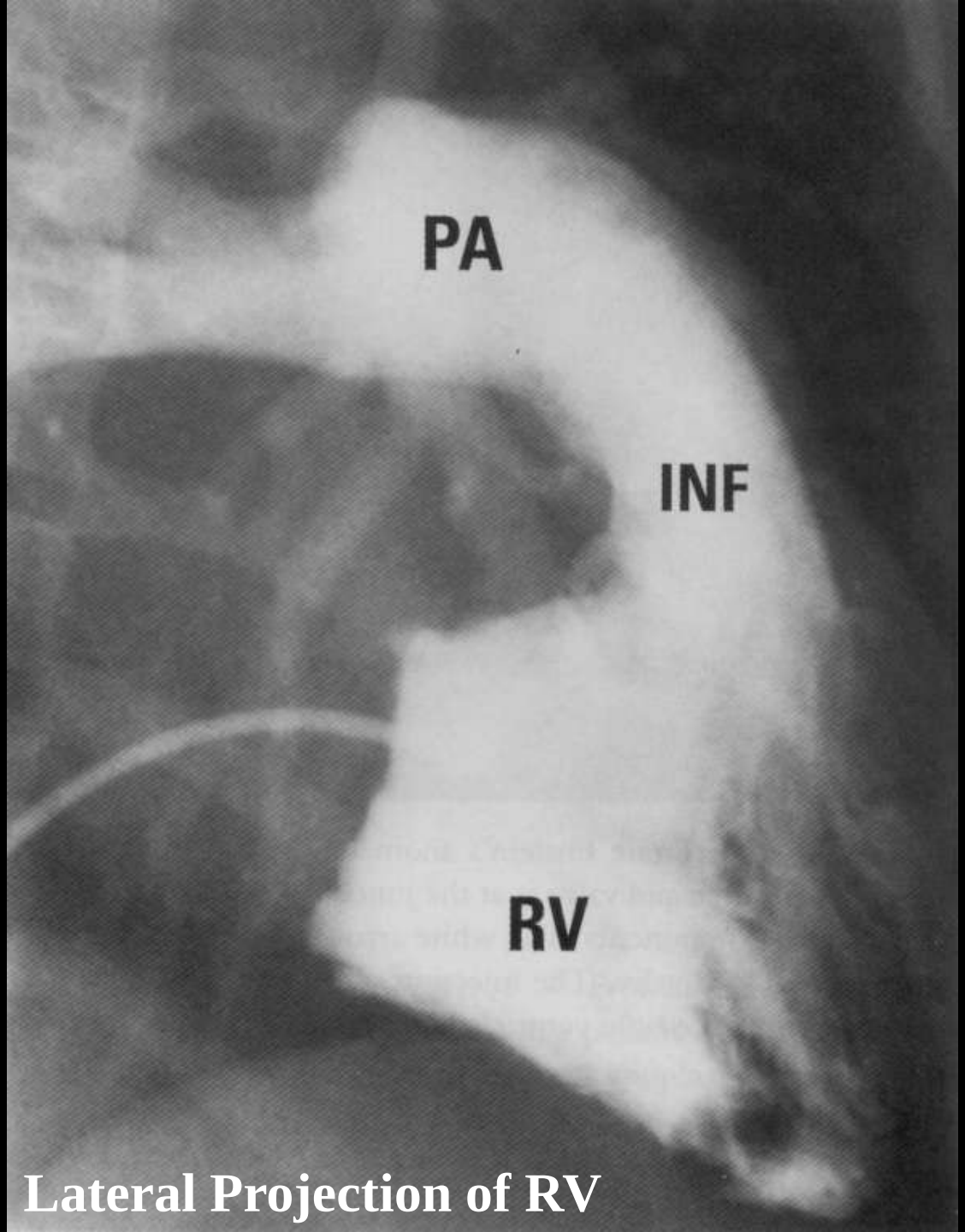
- If the RV is failing and there is shock, perhaps increasing LV afterload with vasoconstrictor may help
  - Increase RV coronary perfusion
  - Increase RV function by septal interaction
- RV infarction hemodynamics may be improved by augmenting LV function
  - Dopamine, etc are rational

Assessing RV Systolic Function

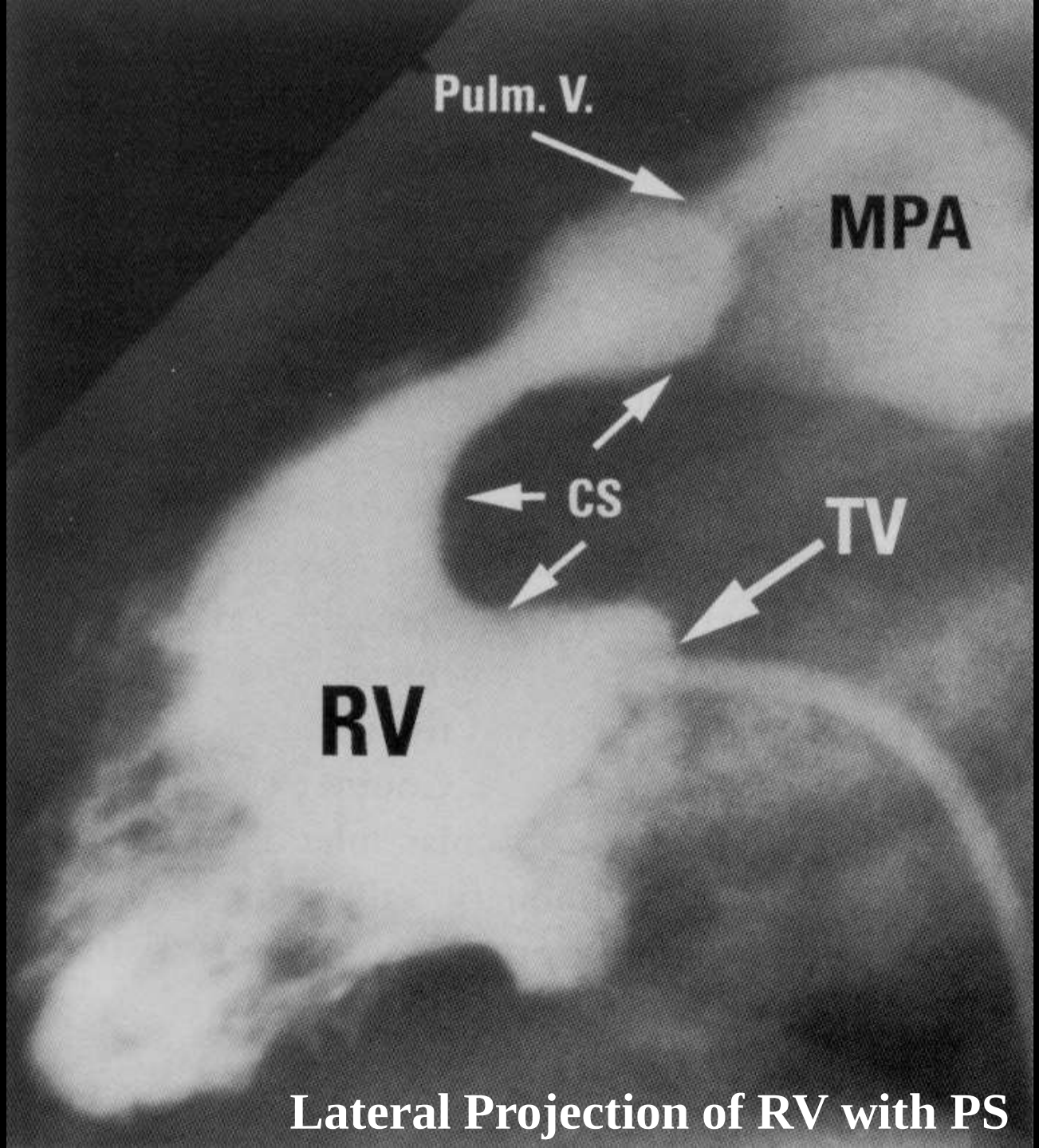
- Preload: surrogate is RA pressure
- Afterload: surrogate is PA pressure
- Contractility
  - Echo: visual estimate
  - Cath:visual estimate
  - Nuclear: calculation
    - First pass, RAO projection, usually higher value
    - Gated blood pool EF >40-45%, lower due to RA overlap (LAO projection to eliminate LV overlap)



AP Projection of RV

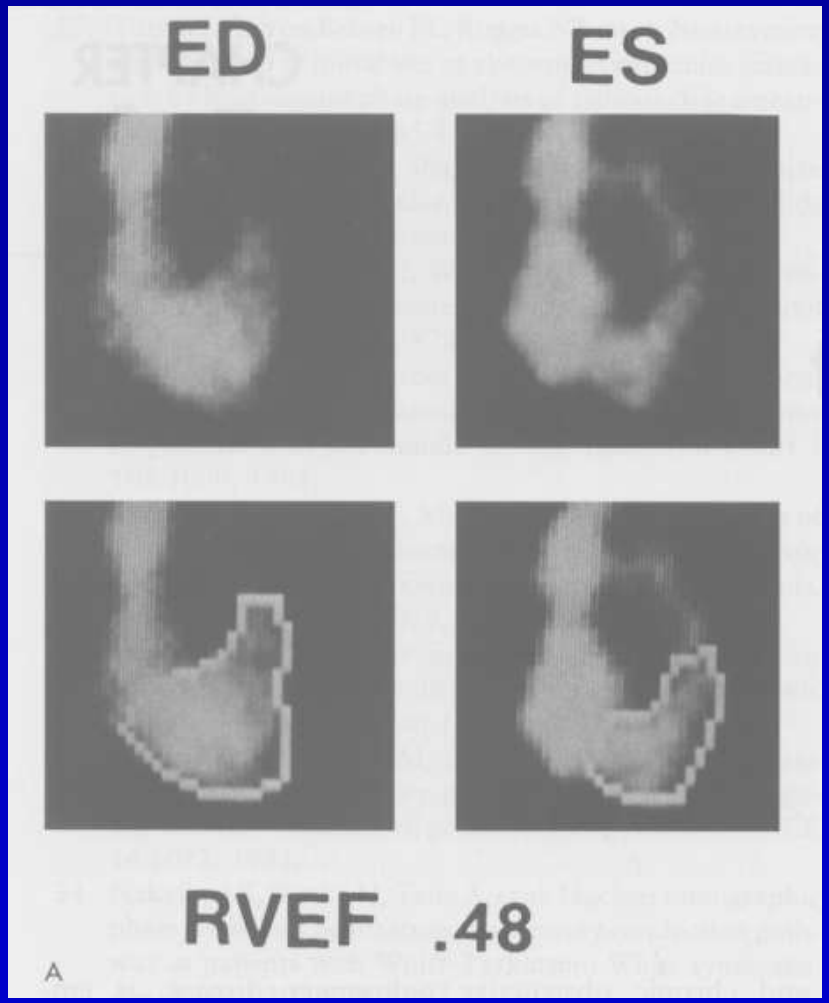


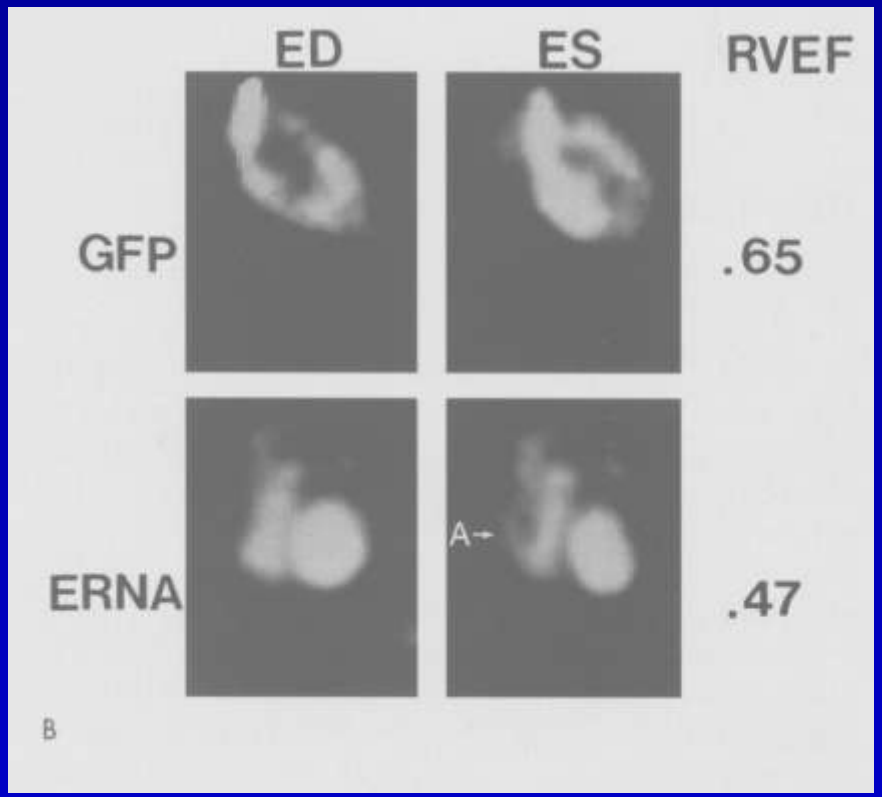
Lateral Projection of RV



Lateral Projection of RV with PS

Nuclear Techniques

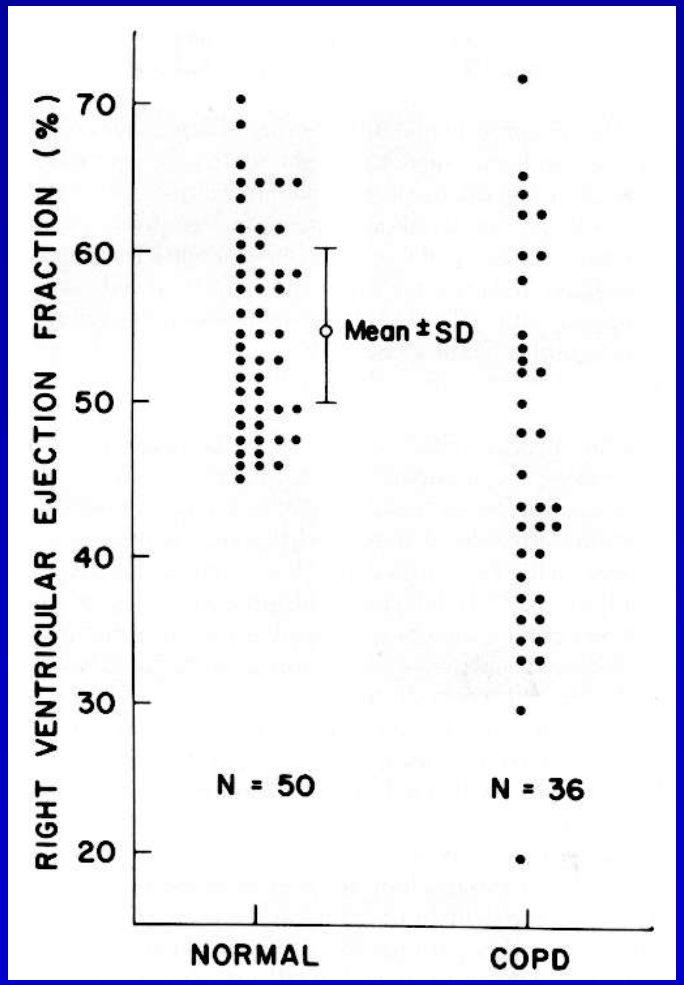


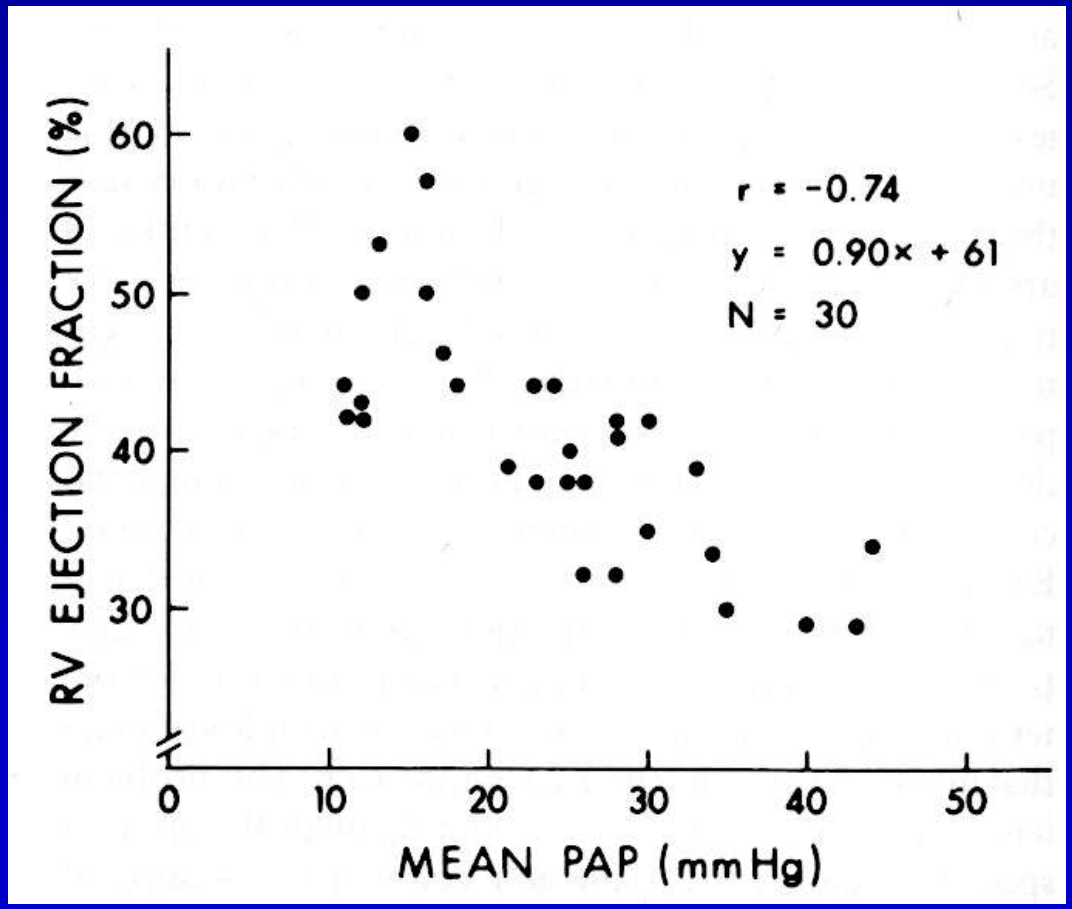


GFP, gated first pass ERNA, equilibrium radionuclide angiogram

Zaret BL, Wackers FJT, 1997

Nuclear Techniques





Berger HJ et al, AJC 1978

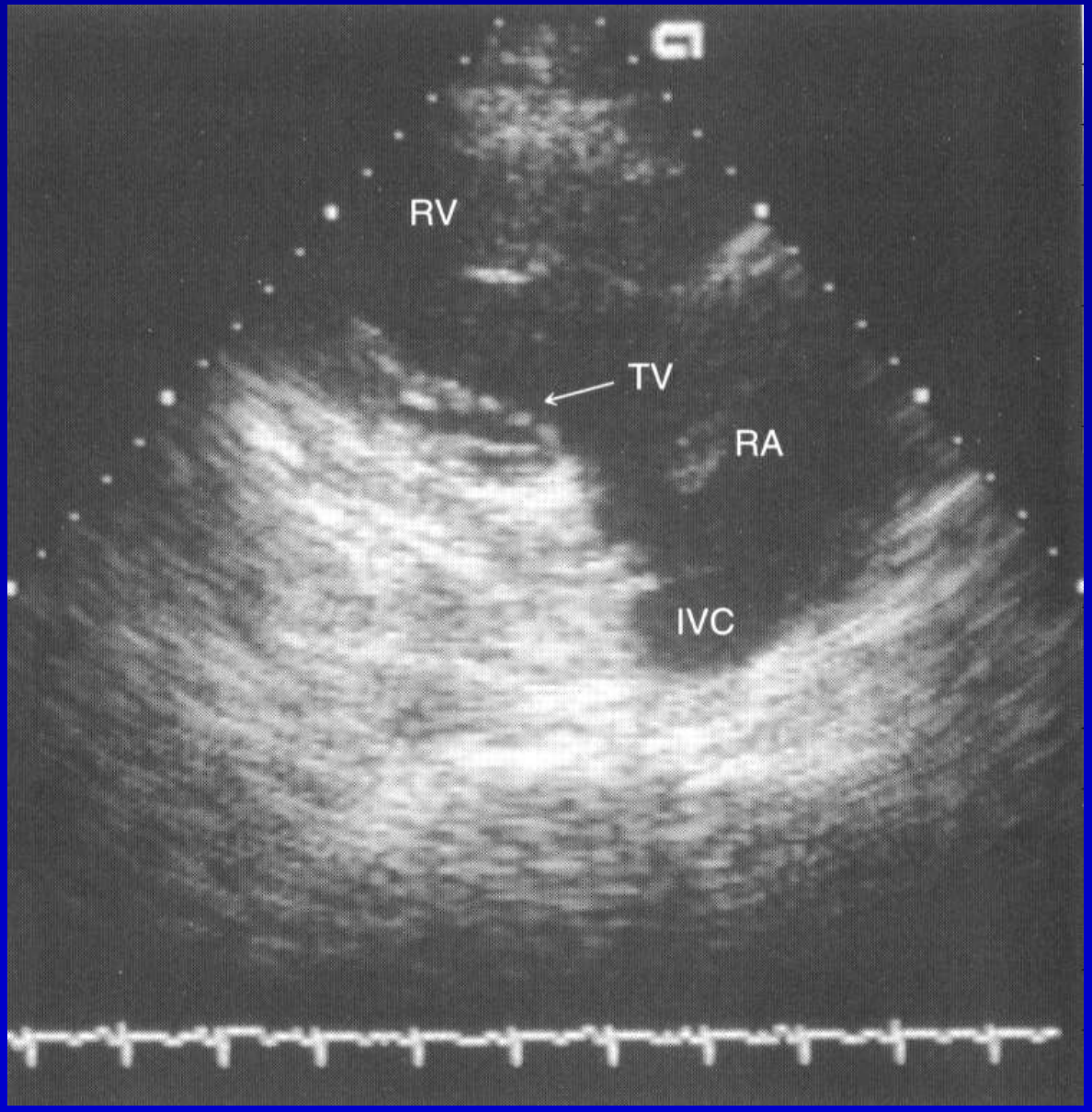
Brent BN et al, AJC 1984

Echocardiographic Assessment of the Right Ventricle

- Transthoracic views: use all possible
  - Parasternal RVIT view and RVOT view
  - Parasternal short axis
  - Apical four -chamber
  - Subcostal four -chamber
- Transesophageal views
  - Transgastric short axis and long axis RV
  - Transesophageal four-chamber

RV Inflow View Structures

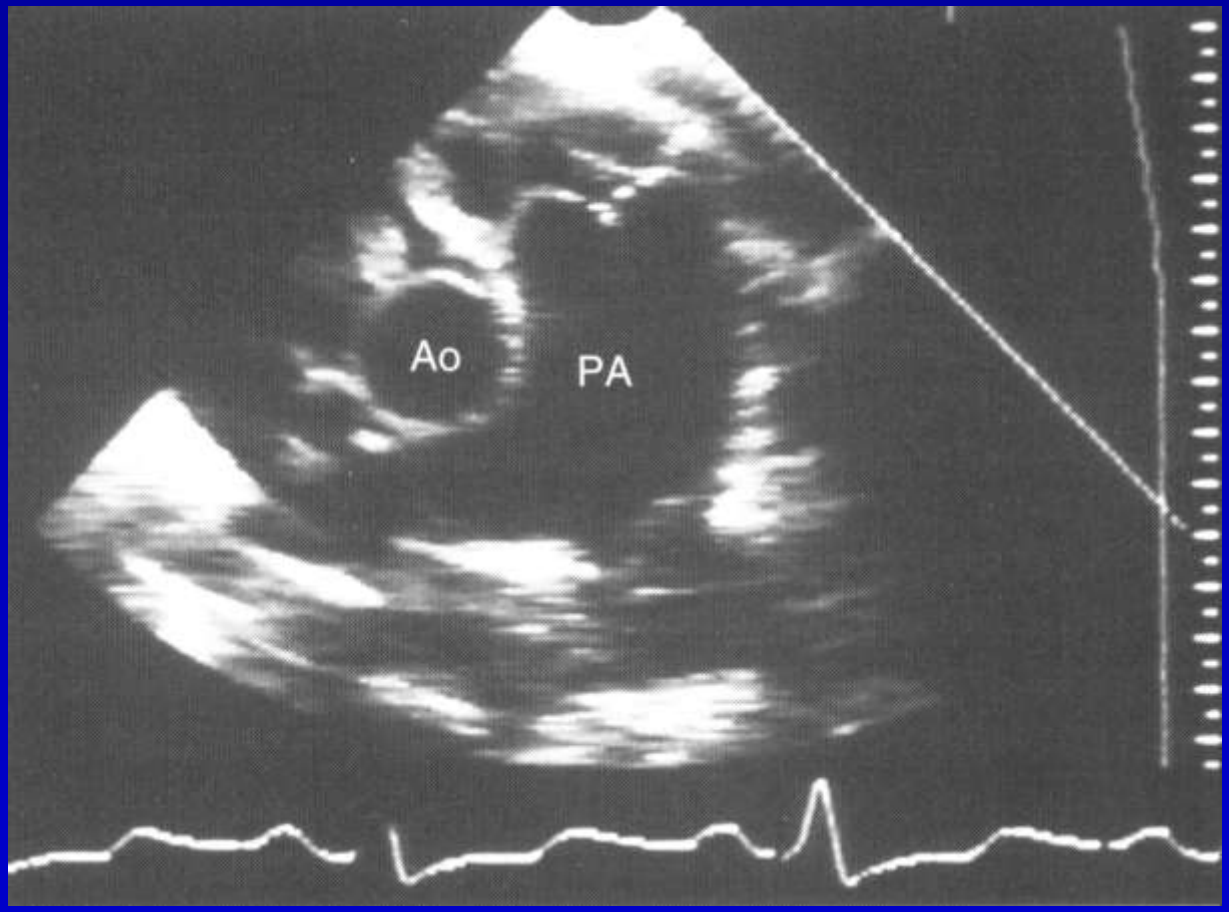
- RV anterior free wall and inferior wall
- Tricuspid valve: anterior and posterior leaflets
- IVC



Otto, 1997, p. 567

RV Outflow Tract Structures

- RVOT
- Pulmonic Valve
- Main PA
- Parasternal short-axis view is best for bifurcation of PA



Otto, 1997, P. 567

RV Assessment in Four-Chamber View

- Geometry
  - Enlargement
  - Wall thickness
  - IV septum
  - Interatrial septum
- Systolic function
- Coronary sinus (posterior angulation)

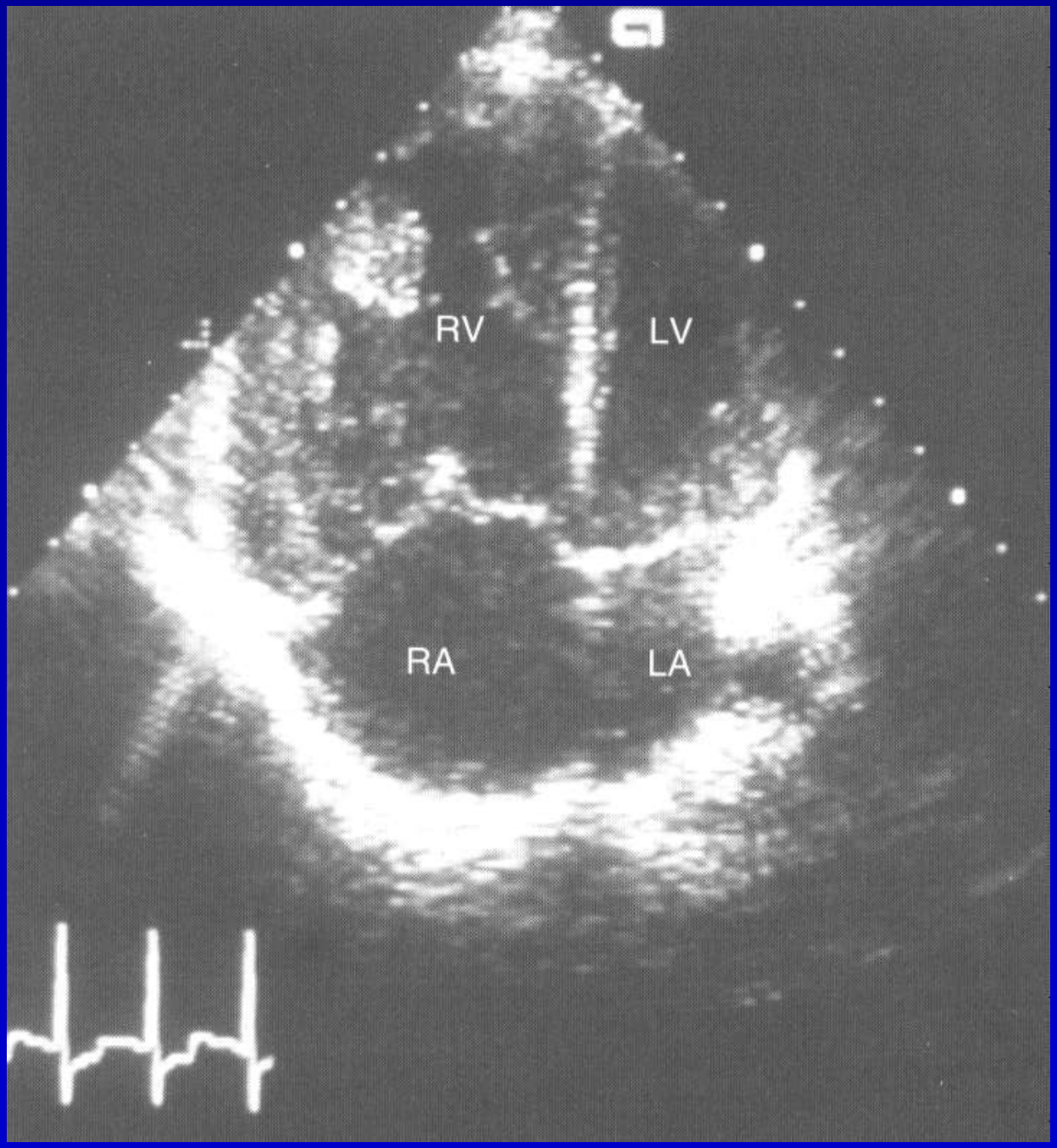
RV Assessment in Subcostal View

- IVC dimension and respiratory variation
- Atrial situs in congenital heart disease
- Also ASD assessment

Echo Findings in RV Load

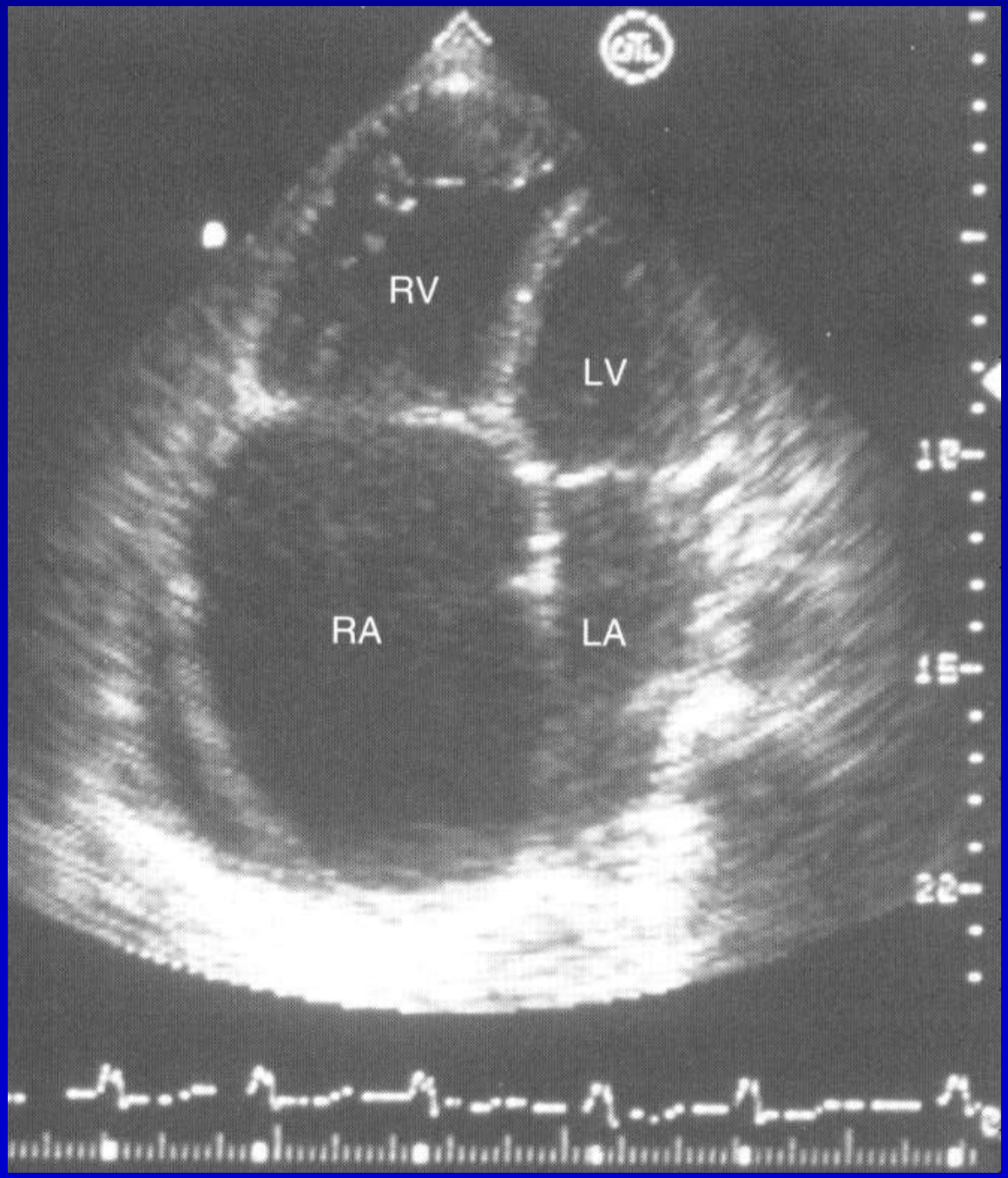
- RV Pressure load
  - RV walls hypertrophy
  - RV dilation occurs early, more evident in short axis than long axis
- RV Volume load
  - RV dilation with preserved systolic function
  - Later, systolic dysfunction
- Septal motion
  - Pressure load: decreased curvature mainly at end systole, normal at end diastole
  - Volume load: decreased curvature mainly in mid-to-late diastole

RV Pressure Load



11-year-old with severe pulmonary hypertension
Otto, 1997, p. 572

RV Volume Load

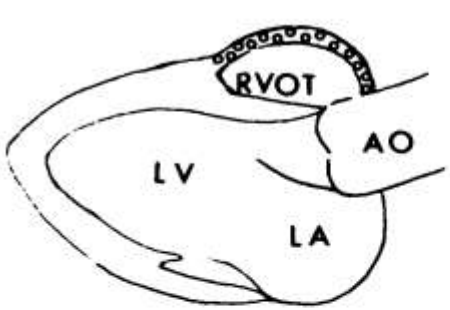


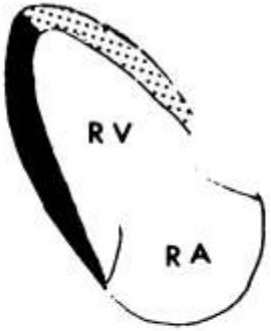
79-year-old with severe tricuspid regurgitation
Otto, 1997, p. 572

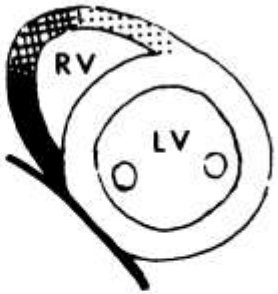
Echo Assessment of the RV

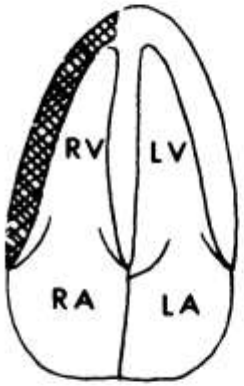
- PS-SA RV should be 60% of LV dimension, Septal-free wall max dimension in diastole is 3.0 (2.5-3.8 cm) and systole is 2.6 (2.0-3.4 cm)
- A4C RV should be 2/3 of LV area
- Volume: no well-validated studies
- Wall thickness: normal is less than 5 mm, best is PS-LA, second is subcostal

Echo Assessment of RV Walls







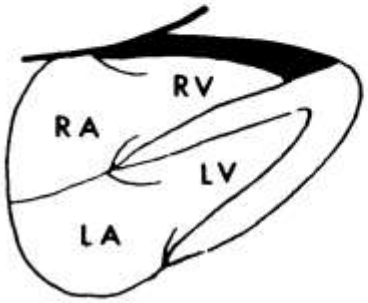


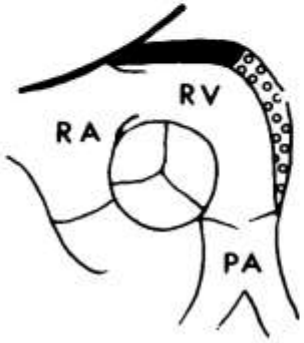
anterior wall of the RVOT

anterior wall of the RV

lateral wall of the RV

inferior wall of the RV





Weyman, 1994, p. 916

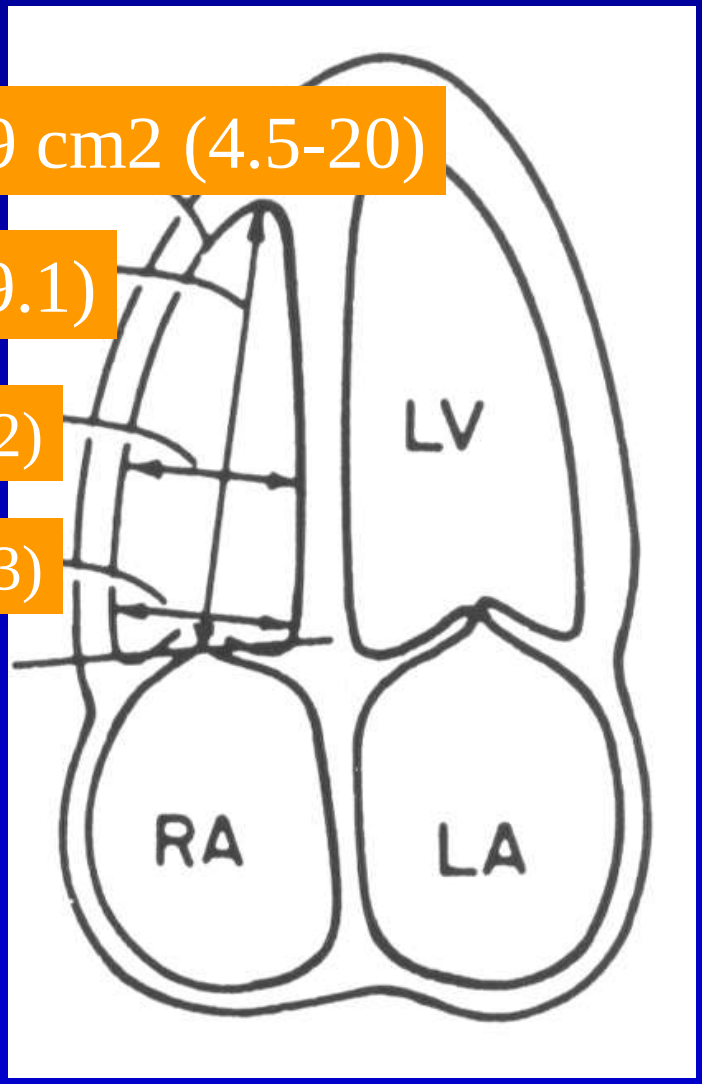
Echo Assessment of RV

Area 10.9 cm2 (4.5-20)

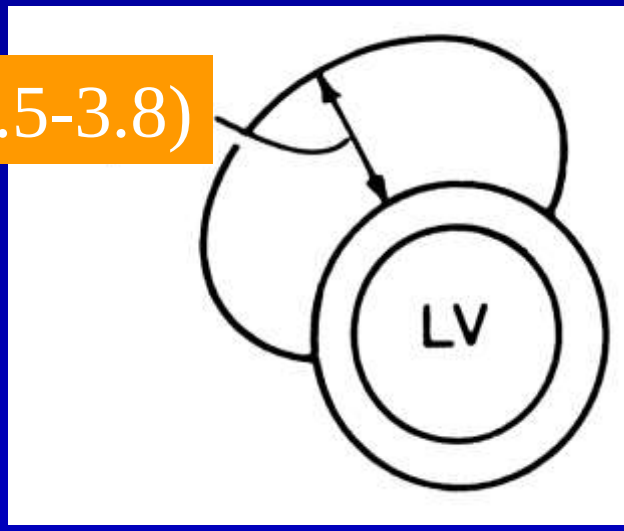
7.1 (5.5-9.1)

3.0 (2.1-4.2)

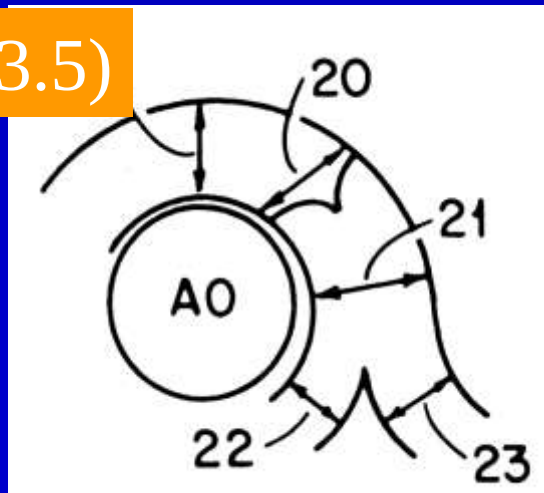
3.5 (2.6-4.3)



3.0 (2.5-3.8)



2.5 (1.8-3.5)



Weyman, 1994

Echo Assessment of RV Dysplasia

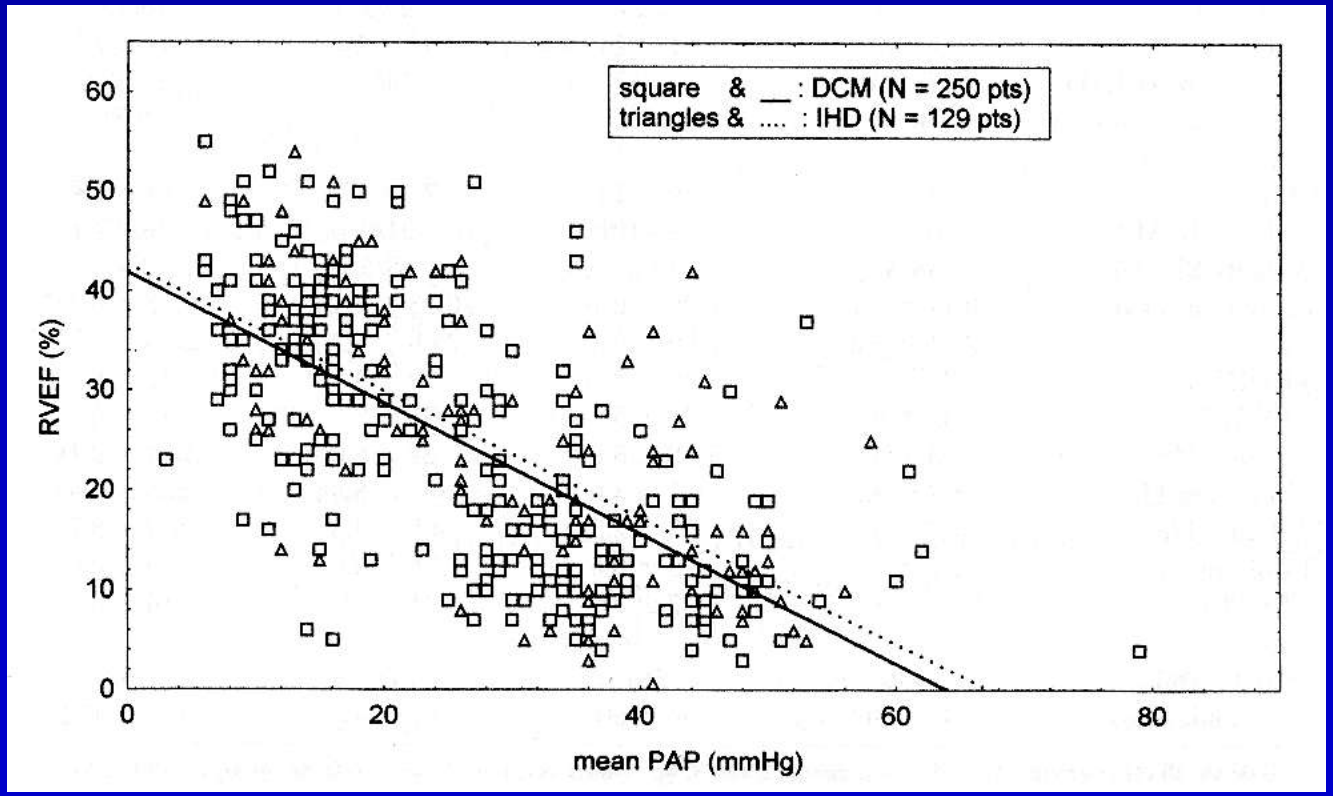
- Most diagnostic finding: localized outpouchings of RV walls are present
- Echo findings are not independently diagnostic

Echo Assessment of RV Diastolic Dysfunction

- Not well defined

Thermodilution Assessment of RV Function

Rapid response thermistor S-G catheter



Ghio S, JACC, 2001

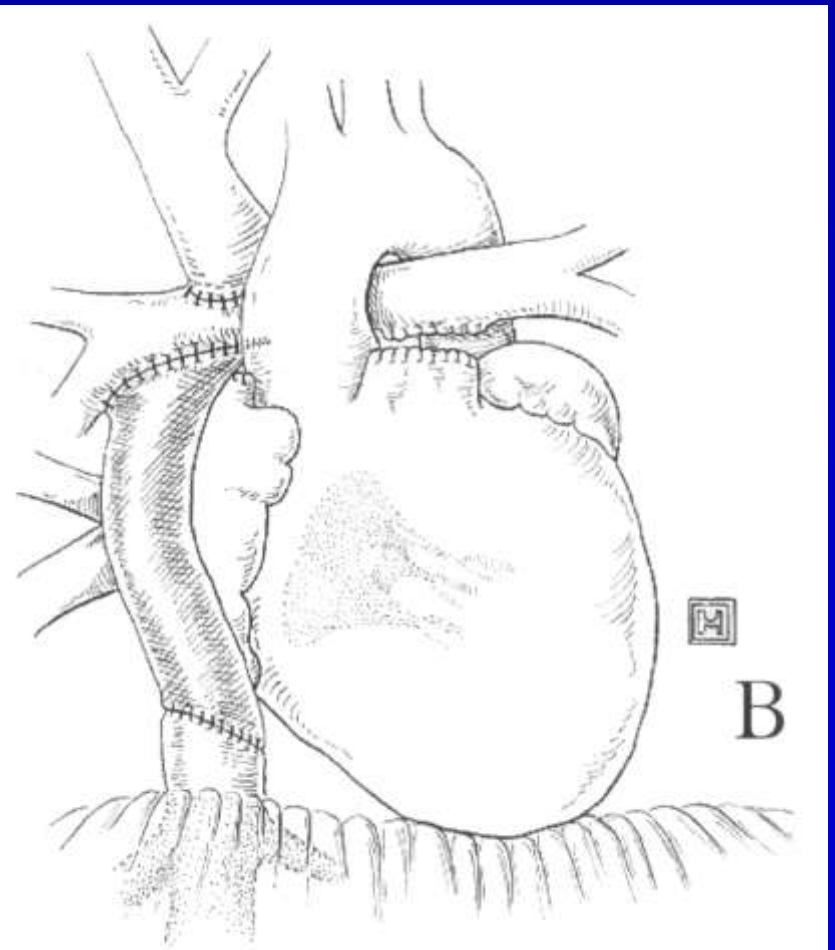
Causes of RV Systolic Dysfunction

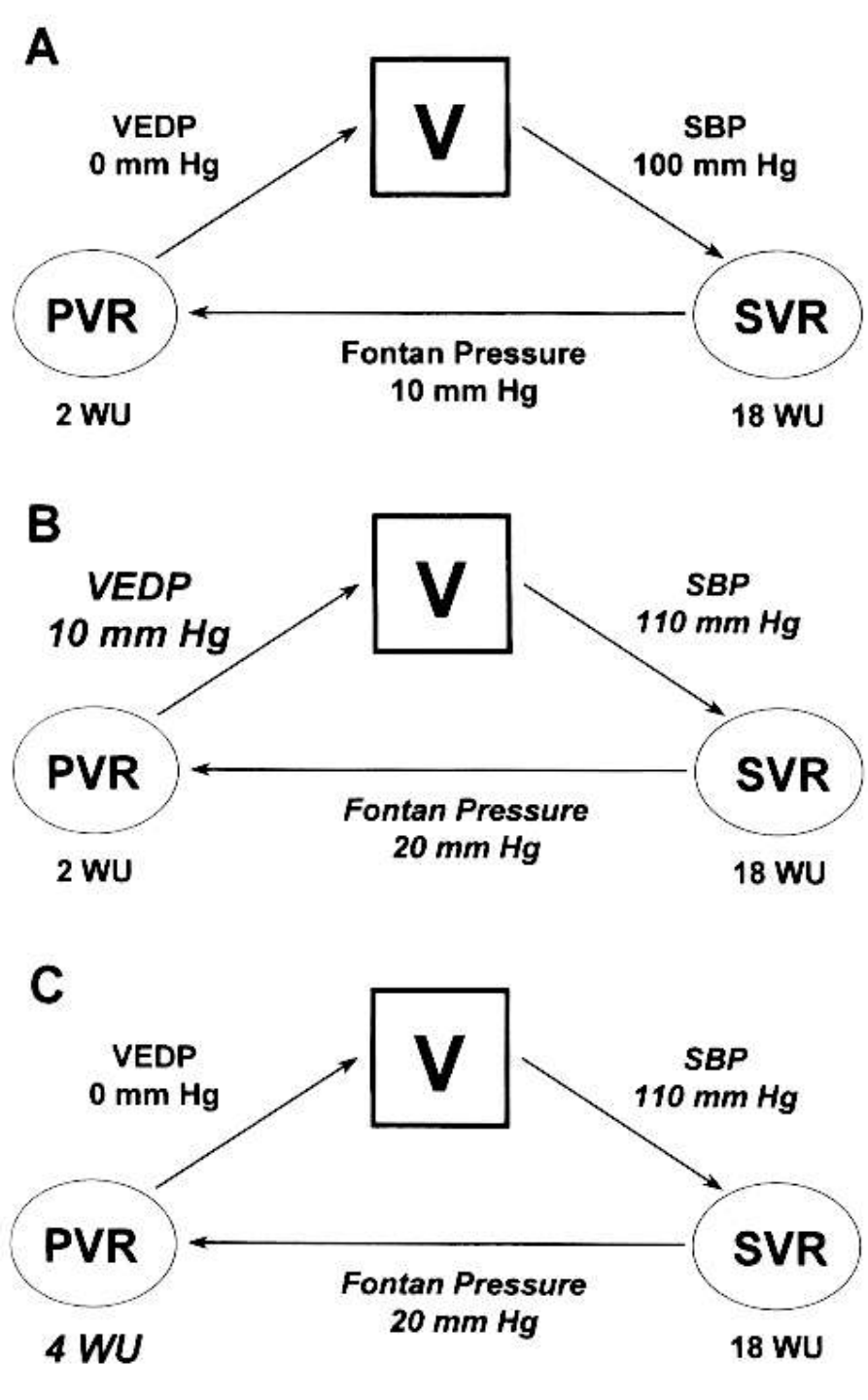
- Elevated afterload
  - PS, increased pulmonary vascular resistance
- Depressed contractility: ischemic or not
  - RV MI
  - RV cardiomyopathy
  - Dilated cardiomyopathy involving the RV

Response of Circulation to Absent RV

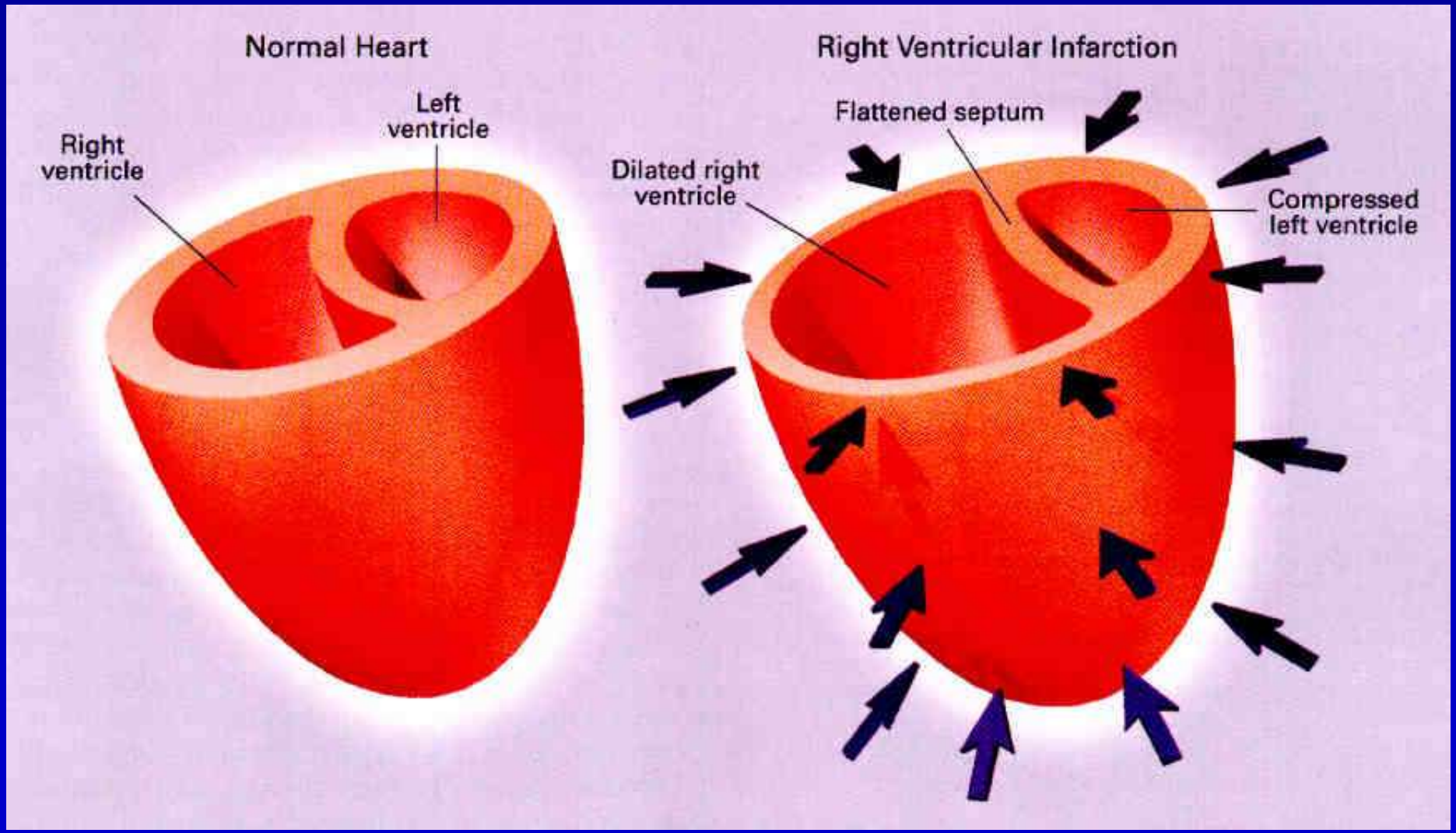
- Fontan Procedure –
  - Cavopulmonary connection
  - Passive flow from vena cavae to pulmonary artery
  - Passive flow through pulmonary circulation to single ventricle
- Problems – Systemic venous congestion
  - High pulmonary resistance
  - Elevated ventricular filling pressure

Response of Circulation to Absent RV





RV Infarction



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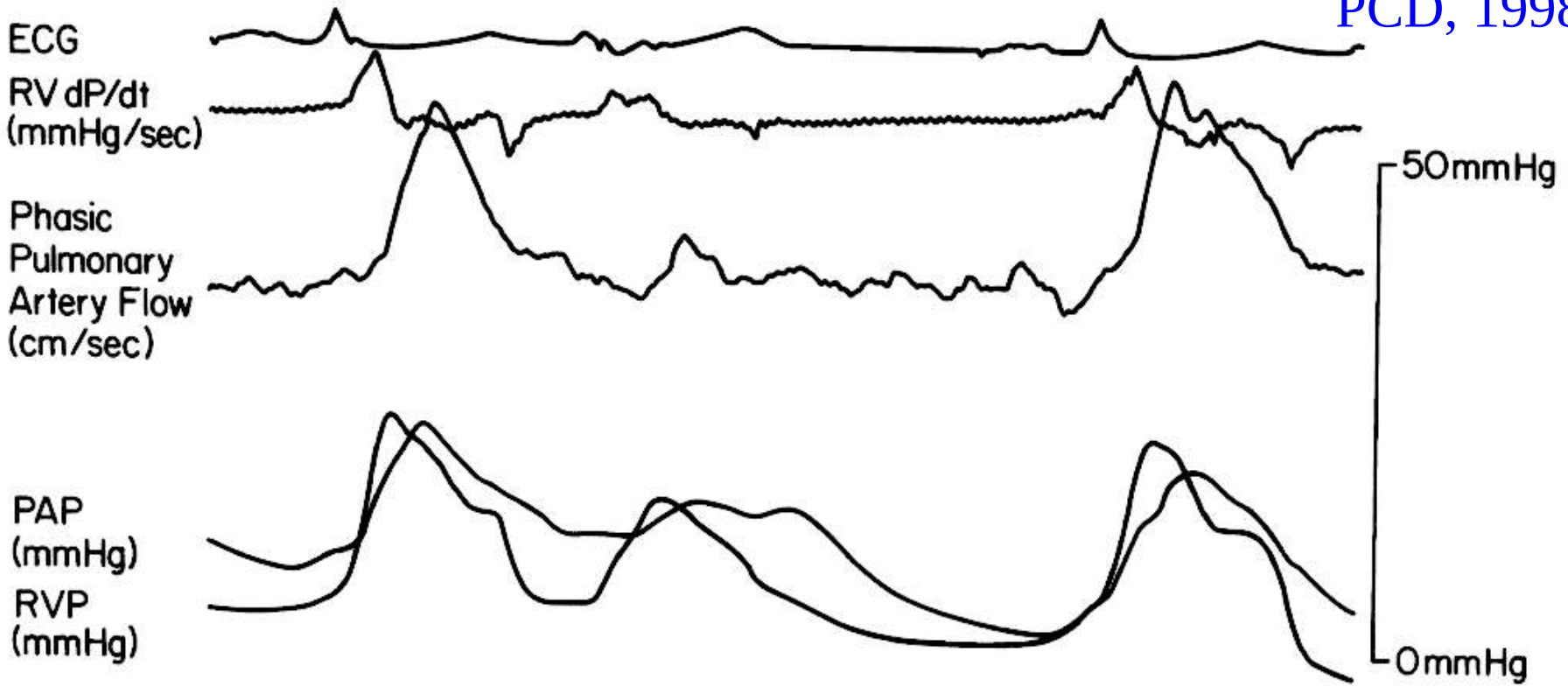
PCD, 1998

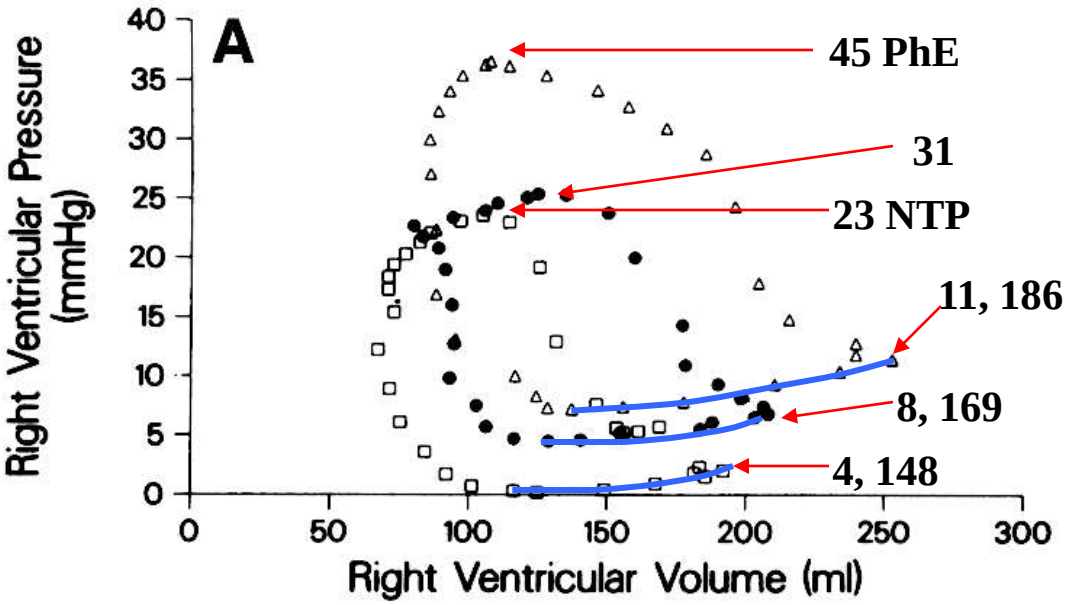

ECG
RV dP/dt
(mmHg/sec)
Phasic
Pulmonary
Artery Flow
(cm/sec)
PAP
(mmHg)
RVP
(mmHg)
50mmHg
0mmHg

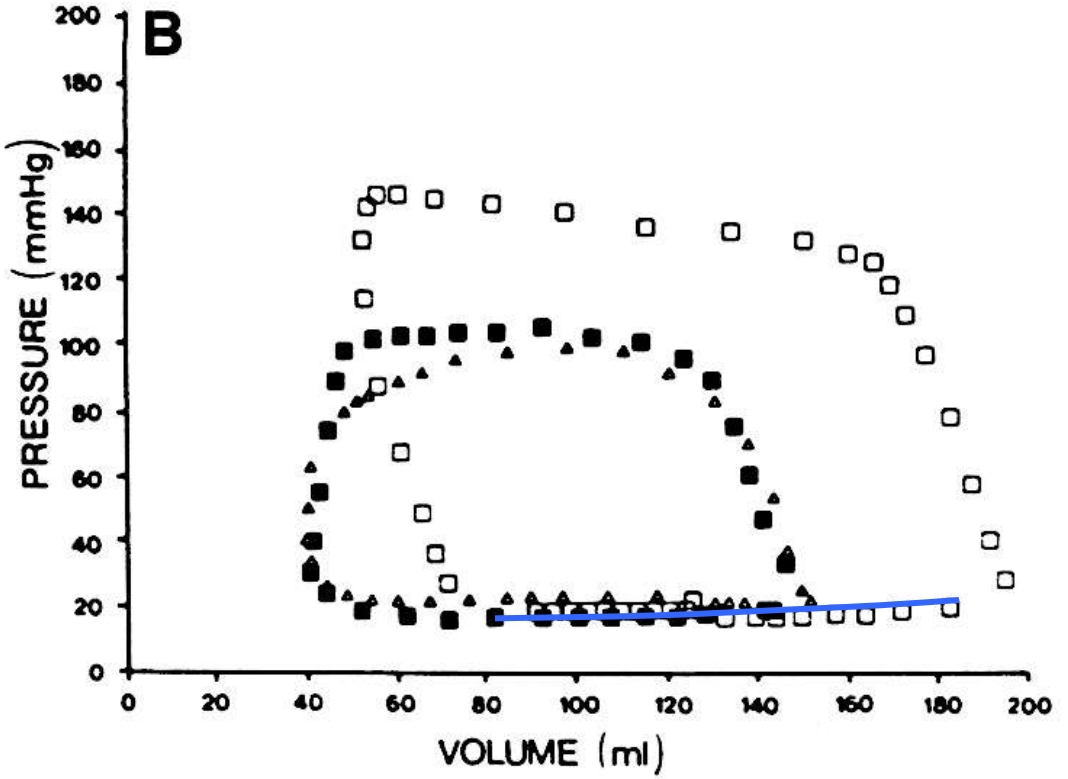
RV systolic performance

Biplane RV gram
And Hi-Fi pressure
In 9 normal patients

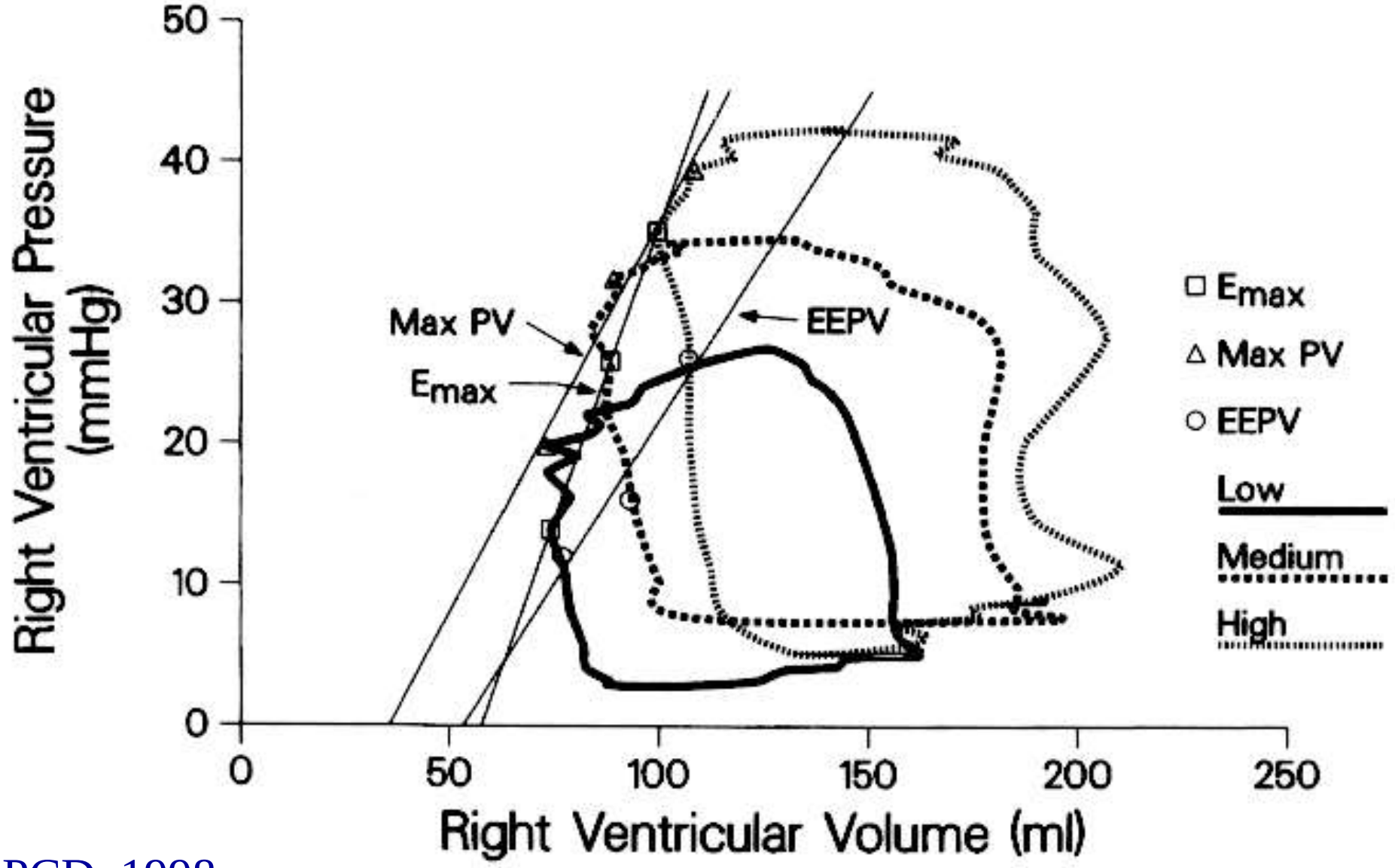
RV curves parallel
upward shift

PCD, 1998 (Circ 1988)

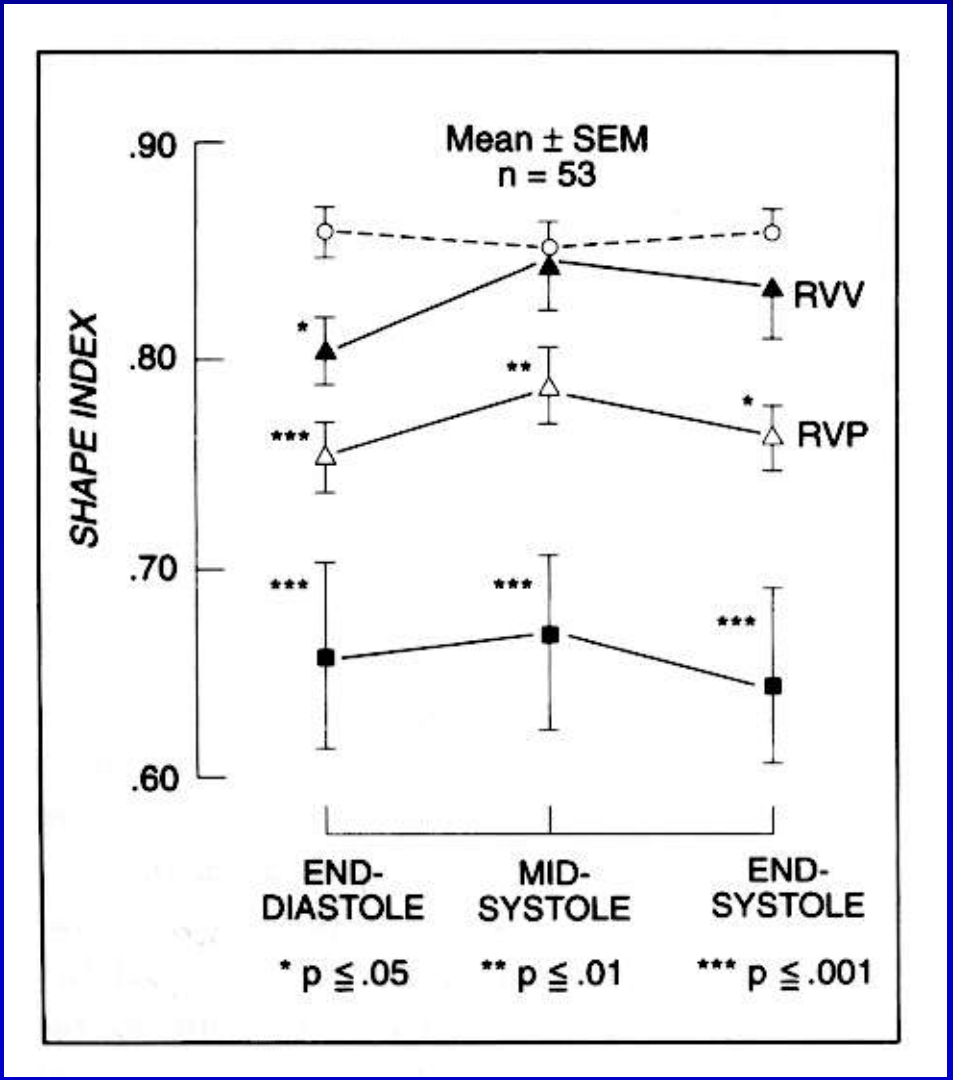




RV systolic performance



PCD, 1998



Normal RVVO

RVPO

Combined

Askah KJ, et al. Canadian J Cardiol 1990